JOURNAL OF AGRICULTURAL RESEARCH

VOL. 34 WASHINGTON, D. C., MARCH 1, 1927 No. 5

STERILITY AND FERTILITY IN THE STRAWBERRY[1]

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SEX TYPES AND STERILITY

In the cultivated strawberry two sex forms, pistillate and hermaphrodite, are recognized. Although plants of pistillate-flowered varieties are reported to produce stamens occasionally, they have never been observed by the writer to do so. Instead, they produce staminodia, which do not contain even abortive pollen. Staminodia are seen as small white projections surrounding the pistils.

Plants of pistillate varieties commonly set all their flowers. Although plants of hermaphrodite varieties ordinarily produce flowers having both stamens and pistils, some of the flowers of many varieties so not contain stamens. In rare cases also flowers of this form have been produced which lack pistils entirely. (Fig. 1.) Plants of hermaphrodite varieties do not ordinarily set all their flowers; many of the later ones on an inflorescence may be sterile.

There is a marked difference between the fertility of hermaphodite varieties grown to-day and that of those raised 75 years ago (*1*).[2] Varieties grown in 1850 set only 15 to 20 per cent of their flowers; present varieties set on an average about 66 per cent and some set as high as 100 per cent.

Self-sterility and cross-sterility, common in other fruits of the rose family, have not been found in the cultivated strawberry. Pistil sterility of hermaphrodite varieties is the only important type of sterility in this fruit. It is and always has been one of the outstanding problems in the development of the strawberry. (Fig. 2.)

Valleau (*7*) has shown that pollen abortion is common in cultivated varieties of strawberries. Ordinarily this is of little importance commercially among cultivated varieties. In the Glen Mary and Progressive varities, however, lack of pollination, resulting from the scarcity of the good pollen grains, may cause some "nubbins." In all cases thus far observed pollen grains similar in appearance to those of a good species have been found to fecundate fertile pistils of any variety in the same chromosome group.

RELATION OF SEX TYPES TO SPECIES

Longley (*3*) has recently pointed out that the 7-chromosome species, *Fragaria vesca*, *F. nilgerrensis*, and allied forms are characterized by the production of only hermaphrodite flowers, all of which

[1] Received for publication Oct. 5, 1926; issued April, 1927.

[2] Reference is made by number (italic) to "Literature cited," p. 411.

set. The 21-chromosome species, *F. elatior*, and the 28-chromosome species, *F. chiloensis*, *F. virginiana*, and allied forms have a variety of sex-flower types. Some seedlings in each 28-chromosome species studied bear pistillate and others hermaphrodite flowers, the hermaphrodite-flowered forms exhibiting a series of sex types ranging from those setting all flowers to those setting none.

The cultivated varieties of Europe and America are supposed to have descended in part at least from plants of *Fragaria chiloensis* taken to Europe in 1714 by Frezier. Wilson Popenoe has recently

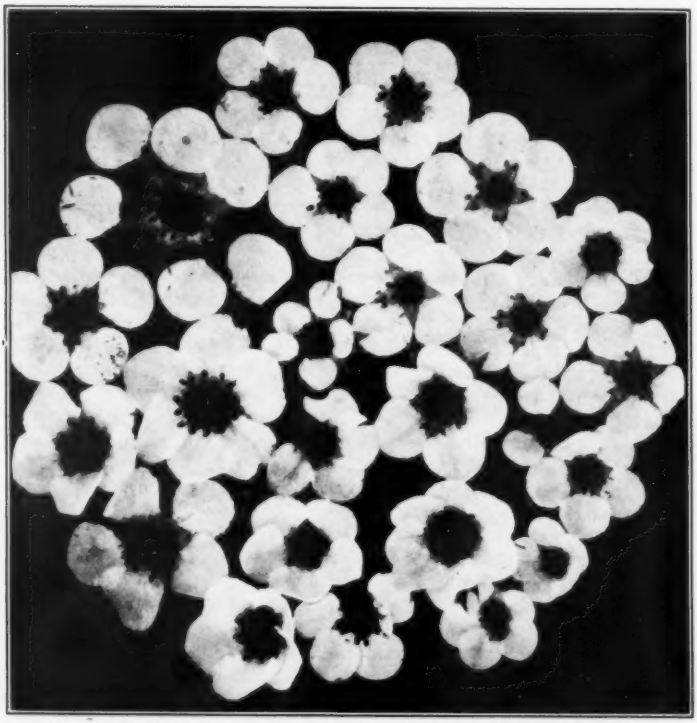

FIG. 1.—Flower types of the Howard 17 strawberry. Flowers with all parts present, some lacking part or all of the stamens, and one lacking pistils, are shown

reintroduced what he regards as the same variety. It is hermaphrodite-flowered and under conditions at Glenn Dale, Md., its flowers are mostly sterile. (Fig. 3.) Of several hundred crosses of *F. chiloensis* with cultivated varieties at Glenn Dale, most showed similar sterility. Though Duchense and many later writers refer to Frezier's plant as pistillate-flowered, Popenoe has stated that he has never seen a pistillate variety of this species under cultivation in any part of South America. All the hermaphrodite seedlings of *F. chiloensis* from the Pacific Coast recently placed under cultivation at the Bell Horticultural Field Station at Glenn Dale, Md. were nearly or

FIG. 2.—Seedlings of *Fragaria virginiana* No. 27 (pistillate) × Marshall; that to the left (pistillate) has set all flowers; that to the right (hermaphrodite) has set none. Photograph taken June 25, 1924

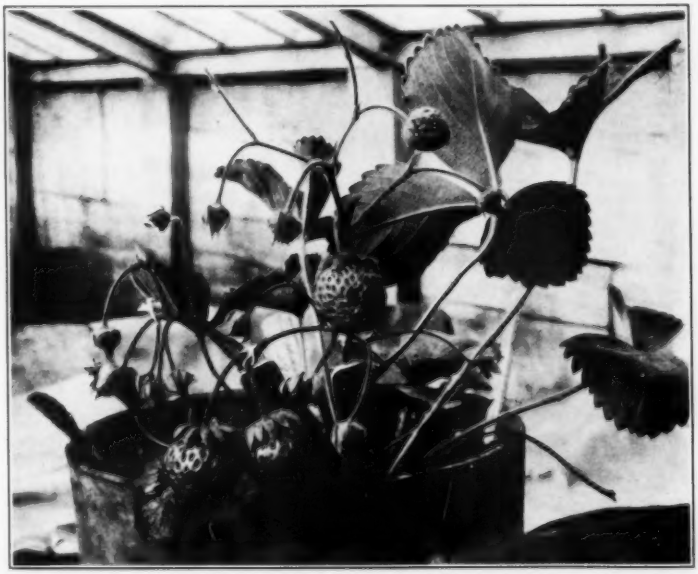

FIG. 3.—The Chilean strawberry brought to this country by Wilson Popenoe. It has long been grown in South America and is supposed to be the same variety as that taken to France by Frezier in 1714. Note that four fruits have set seeds and two others have set a few seeds. Thirteen flowers were sterile

entirely sterile. Pistillate seedlings from the same source set all their flowers. Examination of large numbers of *F. chiloensis* near the mouth of the Columbia River on both the Oregon and Washington coasts in 1926 showed the same condition. The pistillate plants set all their flowers. Most of the hermaphrodite ones were sterile although some bore more or less fruit.

FIG. 4.—Fruit cluster of Little Scarlet, a variety of strawberry long grown in Europe for jam. It is probably an American selection of the wild *Fragaria virginiana*. Five flowers out of nineteen set fruit. On heavy soils at Geneva, N. Y., a much larger percentage sets fruit. Photograph taken June 12, 1924

To obtain the European strawberry of to-day, selections of *Fragaria virginiana* were crossed by the early breeders with *F. chiloensis*. It has been possible to procure from England the Little Scarlet variety, one of these early selections. At Glenn Dale, Md., this variety shows sterility comparable to the Chilean variety introduced by Popenoe. (Fig. 4.) Crosses of it with cultivated varieties are

apparently even more sterile than similar crosses with the Chilean. Valleau (*7*) reports that in the wild, a large part of the hermaphrodite forms of *F. virginiana* are sterile while pistillate varieties set all their flowers. *F. chiloensis* and *F. virginiana*, from which cultivated varieties are chiefly or wholly derived, apparently exhibit similar sex types and sterility.

CORRELATION OF STERILITY AND STAMEN PRODUCTION

Valleau (*7*) points out that pistillate flowers occur on hermaphrodite varieties and that when they occur on hermaphrodite-flowered seedlings which usually are entirely sterile, such pistillate flowers set fruit. Records previously published (*1*) show that the pistillate flowers found on hermaphrodite varieties are commonly the first flowers to open on an inflorescence; that is, they are the primary and secondary flowers. The first flowers to open, the primary and secondary ones, are also most likely to set on hermaphrodite varieties. All or commonly all pistillate flowers set fruit, and sterility tends to appear only when stamens are produced.

PISTILLATE FLOWERS ON HERMAPHRODITE VARIETIES

The frequency with which pistillate flowers are found on hermaphrodite varieties has been shown by the writer. Occasionally when cool weather prevails and flowering is delayed these first flowers are not pollinated and the extent of the occurrence of such pistillate flowers assumes some importance.

The occurrence of pistillate flowers on hermaphrodite varieties varies in different years. In 1925, for example, 28 varieties at Glenn Dale, Md., showed pistillate flowers on which none were noted in 1926. Fruit-bud studies (*3*) indicate that in the primary flowers at least, stamens develop in the fall nearly to the pollen-mother-cell stage, in all but the latest formed plants in northern States. Fall conditions affect considerably the development of the sex organs in certain varieties, inhibiting the formation of anthers in many of the first flowers to differentiate.

INTERMEDIATES BETWEEN HERMAPHRODITE AND PISTILLATE VARIETIES

Valleau (*7*) has reported intergrades in hermaphrodite varieties from those setting all or nearly all of their flowers to those setting no flowers. These intergrades are in reality males having pistils which are not functional. Heretofore, no instances have been noted in which intergrades between hermaphrodite and pistillate varieties have occurred. Two such intergrades have apparently been found among the selections resulting from the practical breeding work of the Bureau of Plant Industry at Glenn Dale, Md. The first is No. 503, a selection of Ettersburg 445 × Howard 17. A count on this selection, May 11, 1926, early in the blossoming season, showed 38 pistillate flowers, 54 with all stamens abortive, and 74 with one or more good stamens. On May 15 the same plants showed 23 pistillate flowers, 20 with abortive stamens, and 84 with one or more good stamens.

The other selection, No. 799, Portia × Kalicene, had on May 11 only 4 pistillate flowers, 69 with abortive stamens, and 39 with one or

more good stamens. Of these, 29 primary flowers had abortive stamens and 6 had some good stamens. Three secondary flowers were pistillate, 32 had all abortive stamens, and 24 some good stamens. One tertiary flower was pistillate, 8 had abortive stamens, and 9 some

FIG. 5—Selection No. 799, Portia × Kalicene, which is apparently an intermediate between a pistillate and a hermaphrodite variety. Some flowers are pistillate, others have abortive stems and still others have good stamens. Photograph taken May 14, 1926

good stamens. Although no counts were made, it was observed that most of the last flowers to open had good stamens It is possible that these two selections, Nos. 503 and 799, represent intermediate stages between pistillate and hermaphrodite varieties. (Fig. 5.)

Attention should also be called to a hermaphrodite variety, Rockhill, which, under conditions at Glenn Dale, Md., sets nearly all of its flowers. A count of 20 plants showed an average of 37.2 fruits set, 2.9 flowers not set, and 6.4 flowers, buds, or missing. The set of fruit obtained in the Rockhill compares favorably with that of pistillate varieties. Near by, Sample, a pistillate variety, set an average of 8.6 fruits, 2.3 did not set, and 0.3 were flowers, buds, or missing. Selections of crosses of Rockhill with other varieties show a remarkably high percentage of flowers that set. They also show many pistillate flowers and flowers containing abortive stamens. Whether such a variety should be listed as an intermediate between a pistillate and a hermaphrodite variety is not yet clear.

CHANGE OF SEX

One variety, Ettersburg 121, has, on some soils in Oregon, been reported as the most productive sort, while on other soils a large percentage of its flowers have been sterile and it has been so unproductive as to be unprofitable. After a careful survey, Schuster (*6*), of the Oregon Experiment Station, found it to be most productive on rather heavy soils and least productive on sandy soils. When grown on sandy soil at Glenn Dale, Md., rarely does 1 flower in 50 of the Ettersburg 121 set fruit. The writer's attention has been called by W. A. Taylor, of the Bureau of Plant Industry, to a similar difference in productiveness in the Cumberland Triumph grown some 30 years ago, which was productive on the heavier black soils in the eastern part of the United States but was unproductive on light soils.

C. C. Georgeson, Director of the Alaska Agricultural Experiment Station, has reported (*2*) a change in fertility in the beach strawberry, *Fragaria chiloensis*, which was unproductive when set in good garden soils but when transplanted to sterile volcanic soils became productive. Little Scarlet sets few flowers on sandy soils at Glenn Dale, Md., but on clay soils at Geneva N. Y., it sets most of its flowers. These observations indicate that sterility in the strawberry may be greatly influenced by the soil type. Just what influence the soil does have, however, is difficult to determine.

Valleau (*7*) also cited instances of changes in the sex type of varieties. For example, plants of the Glenville variety which set fruit only occasionally when grown in the greenhouse set over 50 per cent of its flowers the following summer.

European varieties, when grown at Glenn Dale, Md., exhibit sterility to a marked degree. Few of the scores of varieties introduced in the past few years set more than 1 to 3 flowers to each inflorescence. (Fig. 6.) In this case the length of day rather than soil type is the most marked environmental difference, the days being much longer in Europe during most of the growing period than in the United States. Whether difference in length of day or some other influence at the time of fruit-bud formation is actually the cause of the difference in sterility is of course only speculative.

Records have previously been published showing the extent of sterility in cultivated varieties (*1*). Additional records are given in the accompanying tables, as follows: Table 1 shows the average number of fruits and of flowers not setting on 20 hermaphrodite varieties for which records were obtained in 1925 and 1926; Table 2 gives the same data for other varieties.

TABLE 1.—*Average number of fruits and of flowers not setting per plant of 20 varieties of strawberries in 1925 and 1926, Glenn Dale, Md. The data for 1925 are averages of 10 plants, and for 1926 of 30 plants, except as noted*

Variety	1925		1926		Remark.
	Fruits	Flowers not set	Fruits	Flowers not set	
Americus	7.4	7.2	7.2	8.7	
Big Wonder	6.6	23.4	4.3	18.8	Average 20 plants, 1925.
Brandywine	17.1	4.4	10.2	13.0	
Campbell	23.1	9.3	17.7	12.6	
Clark	6.0	9.2	2.3	3.5	
Ekey	9.2	18.2	5.0	13.3	
Excelsior	10.9	1.8	5.7	2.3	Average 25 plants, 1925.
Freemont Williams	5.6	4.5	6.6	4.9	
Glen Mary	11.1	4.1	11.6	4.3	
Gold Mine	15.2	1.0	9.4	2.7	
Howard 17	16.4	2.7	6.7	1.8	Average 36 plants, 1925; 305 plants, 1926.
Judith	13.8	6.2	6.2	3.0	
Lady Corneille	12.6	9.7	6.1	4.4	
Late Stevens	6.1	2.5	4.4	4.8	
Marvel	16.1	7.0	11.2	3.8	
Mascot	10.7	8.4	6.0	3.0	
McAlpine	13.9	11.0	4.7	4.8	
Ozark	10.3	1.0	12.8	1.0	
Pearl	13.0	1.2	19.4	.5	
Progressive (Champion)	16.0	1.8	14.7	1.1	
Average	12.6	6.7	8.6	5.6	
Percentage of flowers not set		36		39	

TABLE 2.—*Average number of fruits and of flowers not setting per plant of strawberry varieties in 1925 and 1926, Glenn Dale, Md. The data for 1925 are averages of 10 plants, and for 1926 of 30 plants, except as noted*

Variety	1925			1926			Remarks
	Fruits	Flowers not set	Others	Fruits	Flowers not set	Others	
Abington	19.3	8.0	0.9				
Ananas de Guemeice (P.)				9.3	0	1.6	
Aroma				3.7	3.1	−.8	Average 100 plants.
Plants rooting by July 15, 1925.				6.0	3.9	−.1	Average 19 plants.
Plants rooting July 15–Aug. 1, 1925.				4.5	3.4	.2	Average 19 plants.
Plants rooting Aug. 1–Sept. 9, 1925.				2.7	2.8	.0	Average 62 plants.
Benson	10.5	11.0	1.3				
Big Late (P)	11.2	.9	3.6				
Bun	22.7	7.0	6.1				
Burrill				5.4	8.4	−1.9	
Chesapeake	12.4	.3	2.4				Average 146 plants.
Cooper	13.1	3.9	1.8				
Delicious	13.6	10.7	2.5				
Doctor Hogg	15.4	1.6	1.5				
Dunlap (potted)				10.7	9.3		Average 69 plants.
Dunlap (in field)				4.7	6.9	.7	Average 307 plants.
Plants rooting by July 15, 1925.				10.1	9.2	2.1	Average 46 plants.
Plants rooting July 15–Aug. 1, 1925.				6.1	8.7	1.0	Average 84 plants.
Plants rooting Aug. 1–Sept. 9, 1925.				2.5	5.3	.2	Average 177 plants.
Eaton				8.2	1.8	.7	
Ettersburg No. 80	11.6	10.7	2.5				
Ettersburg No. 121	.2	17.3	10.7				
Ettersburg No. 121				1.9	5.0	.3	Average 61 trusses.
Ettersburg No. 445 (P)	10.2	0	2.9				
Fendall (P)	20.3	.1	3.0				
Gardners No. 999	9.0	14.7	1.1				
Haverland (P)	33.9	2.9	2.3				
Heflin	13.6	13.8	2.2				

TABLE 2.—*Average number of fruits and of flowers not setting per plant of strawberry varieties in 1925 and 1926, Glenn Dale, Md. The data for 1925 are averages of 10 plants, and for 1926 of 30 plants, except as noted*—Continued

Variety	1925			1926			Remarks
	Fruits	Flowers not set	Others	Fruits	Flowers not set	Others	
Howard 17				6.7	1.0	3.0	Average 305 plants.
Plants rooting by July 15, 1925.				9.6	.6	2.9	Average 59 plants.
Plants rooting July 15–Aug. 1, 1925.				9.5	.8	2.3	Average 76 plants.
Plants rooting Aug. 1–Sept. 9, 1925.				4.5	1.3	1.6	Average 170 plants.
Howard 25 (P)	45.2	2.9	2.2				
Kalicene				8.2	1.1	.4	Average 31 trusses.
Kellogg's Prize (P)	19.9	.5	2.7	12.4	.9	.5	
Klondike				3.8	.7	.8	Average 303 plants.
Plants rooting by July 15, 1925.				5.2	.3	.8	Average 80 plants.
Plants rooting July 15–Aug. 1, 1925.				4.7	.7	.9	Average 85 plants.
Plants rooting Aug. 1–Sept. 9, 1925.				2.3	.9	.7	Average 138 plants.
La Constante	3.0	39.8	1.9				
La Perle	9.1	.8	2.6				
Lupton	5.9	0	.1				
Michel	10.4	3.2	2.1				Average 25 plants.
Missionary				4.2	2.6	.6	Average 488 plants.
Plants rooting by July 15, 1925.				5.2	2.8	1.1	Average 143 plants.
Plants rooting July 15–Aug. 1, 1925.				4.5	2.8	.7	Average 142 plants.
Plants rooting Aug. 1–Sept. 9, 1925.				3.3	2.3	.2	Average 203 plants.
New York	6.8	8.7	1.8				
Orem	7.1	7.1	1.2				
Portia (P)				8.6	0	.3	Average 100 plants.
Rockhill				37.2	2.9	6.4	Average 20 plants.
Sample				8.6	2.3	.3	Average 100 plants.
Plants rooting by July 15, 1925.				13.3	2.3	.7	Average 23 plants.
Plants rooting July 15–Aug. 1, 1925.				9.1	2.1	.2	Average 27 plants.
Plants rooting Aug. 1–Sept. 9, 1925.				6.2	2.5	.2	Average 50 plants.
Shropshire	8.6	1.4	1.2				
Success	15.5	1.9	2.4				
Tennessee				8.4	4.3	2.6	Average 29 plants.
The Queen	4.4	3.5	1.5				
Van Fleet No. 125				6.2	3.1	1.0	Average 100 plants.
Van Fleet No. 125 (with stable manure mulch).				8.8	3.2	1.5	Average 100 plants.
Vanguard				5.8	2.1	.5	
Vineland No. 19322				6.0	.7	.4	
Warfield (P)	31.2	4.3	2.6	13.1	2.9	.3	
White Pineapple	1.2	18.4	.2				
Average 7 pistillate varieties.	31.7	1.7	2.8				
Average 21 hermaphrodite varieties.	10.2	8.8	2.2				

The average number of flowers not setting in 20 varieties of strawberries, as shown in Table 1, was 6.7, or 36 per cent in 1925, as compared to 5.6, or 39 per cent, in 1926—hardly a significant difference. For all varieties the correspondence for the two years is remarkable. Attention is called, however, to certain exceptions. Thus the Brandywine showed a marked change, producing 17.1 fruits and 4.4 flowers not set in 1925 and 10.2 fruits and 13.0 flowers not set in 1926. Late Stevens also showed a marked difference. In 1925 the number of flowers not setting in this variety was less than one-half the number of fruits not setting, as contrasted with more

flowers than fruits not setting in 1926. Both Brandywine and Late Stevens showed a decided increase in sterility in 1926 over 1925.

The close agreement in both years in such varieties as Big Wonder, which showed a relatively large number of flowers not setting; in Americus with almost an equal number of flowers not setting and of fruits; and in Gold Mine, Howard 17, Ozark, and Pearl, which showed few flowers not setting, is noteworthy.

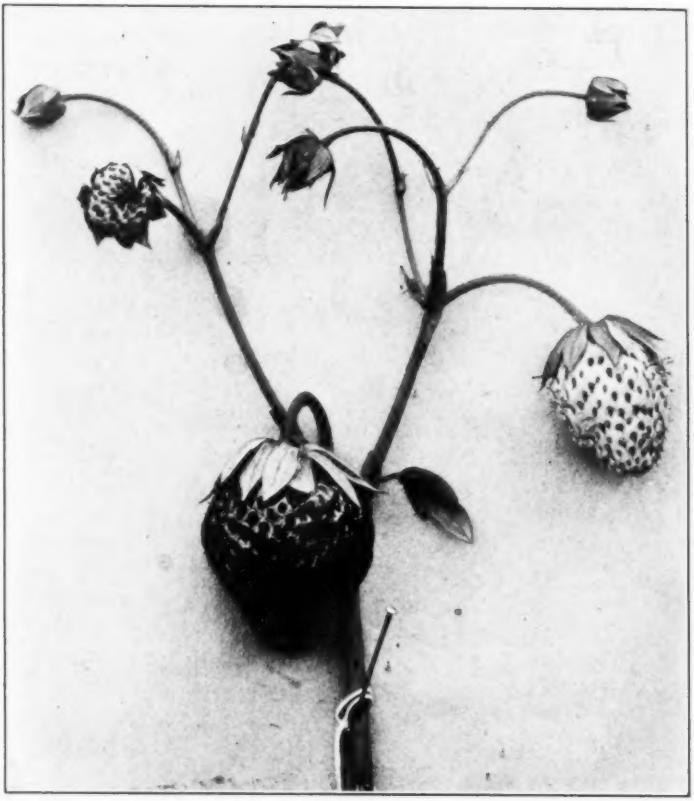

FIG. 6.—A fruit stem of Utility, an English strawberry, showing the primary and two secondary berries set; the rest did not set

At the bottom of Table 2 is given the average of the 7 pistillate and 21 hermaphrodite varieties on which records were obtained in 1925. Pistillate varieties produced an average of 1.7 flowers and hermaphrodite varieties 8.8 flowers, which did not set. The difference between the number of pistillate and hermaphrodite varieties not setting flowers is 6.1, or 37 per cent. It is probable that this difference represents the actual number of sterile flowers which would not set under any conditions.

EFFECT OF FALL CONDITIONS ON STERILITY

In the northern and northeastern part of the United States, the fruit buds of the strawberry differentiate in the autumn. The first traces of fruit buds were found by Ruef and Richey (*5*) in Iowa by the middle of September. Fruit buds develop rapidly and show well-developed pistils and stamens before winter. In some varieties, anther development in the primary and secondary flowers proceeds nearly to the pollen-mother-cell stage before winter.

Ventilated boxes constructed to exclude all light have been placed over dormant plants in the field at Glenn Dale, Md., and kept over them until the blossoming season. The strawberries came into flower in the dark, but in no case was there any apparent development of stamens or petals. Sepals developed to a limited extent

FIG. 7.—The Howard 17 variety, brought into flower in late winter, showing 19 flowers lacking good stamens, 6 of which also lack developed petals. Even the sepals are much smaller than usual. Photograph taken April 11, 1925

only. Other dormant strawberry plants grown in dark constant-temperature chambers behaved in the same way. Light seems to be necessary for the development at least of stamens and petals. Figure 7 shows a plant brought into flower in the short days of winter. Many of the flowers did not produce any good stamens and some did not produce any petals. Usually, under such conditions, the pistils were functional and set fruit although in some cases this did not seem to be the case. It would appear that pistil development proceeded relatively farther than stamen development in the fall.

Gardner in Missouri found no change in the number of fruits on plants of the Dunlap variety following the application of nutrients in the spring. In Michigan, Loree (*4*) increased the set of fruit on plants of the Dunlap variety grown in a very light sand by the application of nitrogen in the spring of the fruiting year. Unfertilized plants set 22.7 per cent of their blossoms, while plants fertilized with

nitrate of soda just before blossoming set 40 per cent. Set of fruit, however, may not be an index of pistil sterility in his experiments. Plants receiving spring applications of nitrogen make a vigorous growth and thus supply ample water and food to their flowers, which weak plants are less able to do. Even though the pistils of the flowers of the weaker plants in Loree's experiment may have been fertile they may not have been supplied with the essentials for further development. A similar test of a pistillate variety might perhaps give similar results even though all the pistils of the variety were fertile. At Glenn Dale, Md., no spring treatment given seems to have affected the proportion of sterile flowers in the spring.

Frost often kills the pistils of the first flowers on inflorescences of varieties which commonly set only these first flowers. When this occurs no later flowers appear to set. The pistils of the first flowers may be killed when the buds are very small, but in no case has any change in the setting been observed. In a seedling (*Fragaria platypetala* × Klondike), which commonly set only the first flowers on an inflorescence, all the primary flowers were picked off before they opened. No increase in the set of later flowers was obtained. Under most conditions pistil sterility seems to be determined in the fall.

A hermaphrodite selection of supposedly pure *Fragaria virginiana* collected by D. N. Shoemaker in the mountains of North Carolina is shown in Figure 8. Its basal truss, which had 6 flowers not set and 19 fruits set, is shown in Figure 9. Figure 10 shows the three higher trusses which produced 20 fruits and also 13 flowers which did not set. As the inflorescence of the strawberry is terminal, new growing points must form before other fruit buds can develop. The basal truss shown is the center one and developed first; new growing points were then laid down, which later formed fruit buds; but on these later-formed inflorescences a slightly larger percentage of the flowers were sterile. Figure 11 shows a potted plant of the Dunlap with a basal and high-branching truss, the first having 5 fruits and 2 sterile flowers and the latter 5 fruits and 5 sterile flowers. Records taken on 31 potted plants of this variety having two or more trusses gave 46 per cent sterile on the earlier trusses and 62 per cent sterile on the later ones.

Examination of other cultivated varieties reveals the same condition as in the Dunlap; the later-formed trusses show greater sterility than those formed earlier. Figure 12 shows a crown of the Howard 17 variety with three trusses, the center one of which set 5 fruits one of which was frosted. The other trusses produced 5 fruits and 4 sterile flowers. It is evident that the later-formed fruit buds exhibit a greater percentage of sterility than do those formed earlier. Whether this is due to climatic, nutritional, or other conditions at the time of fruit-bud formation is not clear.

Ruef and Richey (*5*) reported that the earlier-rooting runner plants formed fruit buds first and that these buds developed to a greater degree in the fall than did those formed later. Table 2 summarizes a record of the number of fruits and sterile flowers produced in 1926 on strawberry plants of leading standard varieties, the runners of which were rooted on different dates in 1925. Thus, on May 24,

FIG. 8.—One plant of selection No. 13 of *Fragaria virginiana*, which has produced several fruit clusters. The earlier flowers set; many of the later ones did not

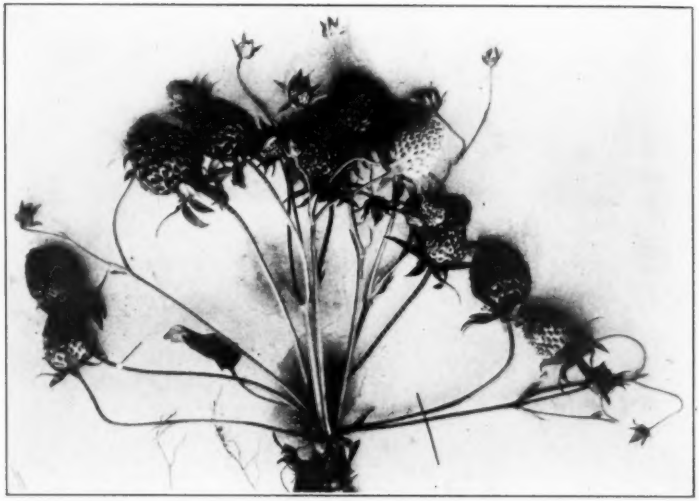

FIG. 9.—The basal truss of the plant shown in Figure 8. Nineteen fruits set and 6 flowers did not. Photograph taken June 12, 1924

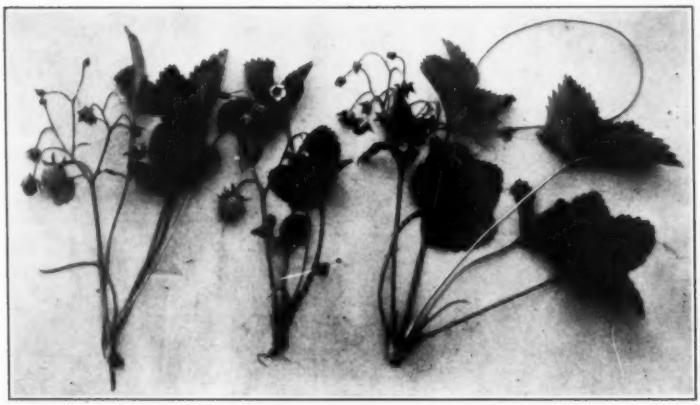

FIG. 10.—Three later-formed trusses of the plant shown in Figure 8. To the right are shown 8 fruits and 5 flowers not set; in the center 6 fruits, 1 flower, and 3 flowers not set; to the left 6 fruits and 5 flowers not set; a total of 20 fruits, 1 flower, and 13 flowers not set

FIG. 11.—Dunlap plant with basal and high-branching clusters. The basal cluster has 5 fruits and 2 sterile flowers; the high cluster 5 fruits and 5 sterile flowers. The basal cluster has also earlier-maturing fruit

1926, counts were made on 303 plants of the Klondike, the most important commercial variety in America, which were rooted on different dates the previous year. Eighty plants, rooted on or before July 15, produced 418 fruits, 21 flowers not set, and 65 others (average 5.2, 0.3, 0.8). Eighty-five plants, rooted between July 15 and August 1, produced 400 fruits, 59 flowers not set, and 80 others (average 4.7, 0.7, 0.9); 138 plants rooted August 1 to September 9 produced 322 fruits, 129 flowers not set, and 102 others (average 2.3, 0.9, 0.7).

FIG. 12.—Howard 17 strawberry plant with 3 fruit clusters. The center was the terminal and formed 5 flowers, one of which was frosted. Later a new growing point developed on each side and a terminal inflorescence formed on each point. On that to the left 2 fruits and 3 sterile flowers, and on that to the right 3 fruits and 1 sterile flower developed

Of the five hermaphrodite sorts, Klondike, Howard 17, Aroma, Dunlap, and Missionary, the average was 60 per cent fruits and 28 per cent flowers not set for the plants rooted earliest; 58 per cent fruits and 32 per cent flowers not set for late July plants; and 51 per

cent fruits and 41 per cent flowers not set for plants rooted in August and early September. In every variety an increase in the percentage of flowers not setting in the later-rooted plants is evident, although the number and percentage of flowers not setting differs with varieties. (Figs. 13 and 14.)

This increase in unfruitful flowers may be attributed to the time of formation of fruit buds, the later-rooting plants forming fruit buds last, or to the relative vigor and food supply of the plants on which

FIG. 13.—Plant of Howard 17 strawberry, rooted in July, which produced 12 fruits and 1 sterile flower

they were borne. If time of fruit-bud formation is the important factor then it may be assumed that the influence of one or more climatic conditions effective at the time of fruit-bud formation directly or indirectly determines the extent of sterility.

From a comparison of the extent of sterility during different years it is evident that factors such as sunlight, temperature, evaporating power of the air, water-supplying power of the soil, length of growing season, or other similar factors were sufficiently different during the fall periods to bring about a change in the degree of sterility in some varieties.

SUMMARY

The two species, *Fragaria chiloensis* and *F. virginiana*, from which cultivated strawberries have largely or entirely developed, have the same chromosome number, and exhibit the same pistillate and hermaphrodite flowered sex types; the latter type shows great diversity from males possessing no functional pistils to those setting many of their flowers.

Under the conditions which prevail at Glenn Dale, Md., plants of the particular varieties of *Fragaria chiloensis* and of *F. virginiana* from which modern varieties may have been chiefly derived are largely sterile.

Two selections are reported as intermediates between hermaphrodite and pistillate forms, the first representatives of such a group yet reported. A hermaphrodite variety, the Rockhill, is reported as behaving, in the setting of its flowers, more like a pistillate than a perfect-flowered variety.

Evidence that sex expression in hermaphrodite varieties is changed by soil conditions has been presented by others and apparently is confirmed. Records covering the setting of flowers and fruit of 20 varieties for both 1925 and 1926 and of many other varieties for one of these years are presented. They show a remarkable correspondence in percentage of sterility in varieties for the two years.

FIG. 14.—Howard 17 strawberry plant, rooted in September, 1925, which produced 8 fruits and 3 sterile flowers

When the floral parts abort or do not develop because of unfavorable conditions the stamens are the first to be affected. Under more extreme conditions petals are lost, sepals next, while pistils are the least likely to be affected.

Although it may affect the actual set of fruit, spring treatment appears not to affect the number of sterile flowers.

The earlier formed trusses and the earlier rooted plants of the previous season appear to have less sterility than those formed or rooted later.

The character of the fall season is considered one of the important causes of fertility and sterility in this fruit.

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A STUDY OF THE FACTORS DETERMINING QUALITY IN SWEET CORN [1]

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INTRODUCTION

The importance of quality in sweet corn as affecting its successful manufacture and sale as a canned product is coming to be more fully appreciated. A thorough understanding, therefore, of just what constitutes quality and what those factors are by which it is affected is desirable.

It is known that seasonal and climatic factors, through their influence on the rate at which the corn develops and matures, play an important part in determining the quality of the canned product.[2] It is apparent also that certain characteristics possessed by sweet corn as distinct from field corn are likewise of very great importance.

Among the various types of corn used as human food a wide variation is known to exist. Earlier investigations [3] on the relation of the variety of corn to the quality of the canned product brought to light fundamental differences in the constitution of sweet and field corns which were reflected directly in the physical appearance and table quality of their canned products. In order, therefore, to gain a better understanding of what constitutes quality, and of the relation of varietal differences to it, the field of the investigations here discussed was extended to include not only the sweet but also representatives of the flint, dent, and flour corns, waxy maize, and other well-known or special types not previously investigated. The results of this study are set forth in the present paper.

To indicate his conception of the probable relationship of the different types of corn, Sturtevant [4] in his taxonomic grouping of the different varieties of corn placed the podded varieties first as the most primitive. Pop, flint, dent, and soft or flour corns in the order named were included in his grouping. He was uncertain as to the relationship of the sweet varieties to the other types. Waxy maize was little known until comparatively recently and hence was not considered in Sturtevant's work.

Whether or not one is justified in assuming any evolutionary relationship between the different types of corn, there are certain physical characteristics that suggest such a relationship. This fact should be kept in mind in the discussion of the present findings.

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[1] Received for publication Nov. 4, 1926; issued April, 1927.

[2] MAGOON, C. A., and CULPEPPER, C. W. THE RELATION OF SEASONAL FACTORS TO QUALITY IN SWEET CORN. Jour. Agr. Research 33: 1043–1072, illus. 1926.

[3] CULPEPPER, C. W., and MAGOON, C. A. STUDIES UPON THE RELATIVE MERITS OF SWEET CORN VARIETIES FOR CANNING PURPOSES AND THE RELATION OF MATURITY OF CORN TO THE QUALITY OF THE CANNED PRODUCT. Jour. Agr. Research 28: 403–443, illus. 1924.

[4] STURTEVANT, E. L. VARIETIES OF CORN. U. S. Dept. Agr., Off. Expt. Stas. Bul. 57, 108 p., illus. 1899.

In the flint corns the endosperm is characterized by a starchy core surrounded by a hard, flinty portion that varies somewhat in thickness in the different varieties. In the dent corns the sides of the kernel are composed of a cornaceous portion, the starchy core being central in location and extending to the tip of the kernel. It is to the shrinkage of this starchy portion that the denting of the kernel is due. In the soft or flour corns little of the tough horny element is present, the contents of the endosperm being made up almost entirely of soft, starchy tissue.

Sweet corn is characterized by a translucent, hard, wrinkled or shriveled endosperm, the shriveling being due apparently to the nature of the polysaccharides contained in it and the manner in which they are laid down. In physical appearance the waxy maize resembles more nearly the corn of the flint varieties, having a hard full kernel. The kernel contents, however, present a waxy appearance when the kernel is split. In chemical composition it more closely resembles the sweet varieties, particularly with respect to the water-soluble portion.

PLAN OF INVESTIGATION

The investigation was carried on during the season of 1925 in the fields and laboratories of the Arlington Experiment Farm, Rosslyn, Va. The location of the test plots and the cultural practices followed in this study were as nearly identical with those of the earlier studies [5,6] as seasonal conditions would permit. The methods of observation, testing, and analysis also were similar.

Nine varieties were studied during the season: Two flour corns, Mandan White and Yellow Assiniboine, from North Dakota; two flint corns, Longfellow and Rhode Island White, from New England; a variety of late sweet corn, which originated in Guatemala; an unnamed variety of waxy maize obtained from the Office of Cereal Crops and Diseases, Bureau of Plant Industry; Second Early Adams, a dent variety widely used by market gardeners for the roasting-ear trade, and obtained from a local seedsman; and two well-known varieties of sweet corn, Golden Bantam and Stowell's Evergreen, from Pennsylvania. The two last-named varieties were planted as checks on the others and also to furnish additional data on these two varieties for comparison with similar data accumulated over a period of several years.

With the exception of three varieties, the plantings in the test covered by this discussion were made May 16. Golden Bantam, Stowell's Evergreen, and Second Early Adams were planted June 26.

To permit of thinning to a uniform stand when the plants were sufficiently well developed, a heavy seeding was made. Standard cultural practices were followed throughout the growing season.

As in previous studies, the rate of development of the corn and the tagging of ears were recorded to facilitate later sampling.

Sampling for chemical analysis, for determination of yields and degree of toughness, as well as for canning tests, was performed as usual.

[5] CULPEPPER, C. W., and MAGOON, C. A. Op. cit.
[6] MAGOON, C. A., and CULPEPPER, C. W. Op. cit.

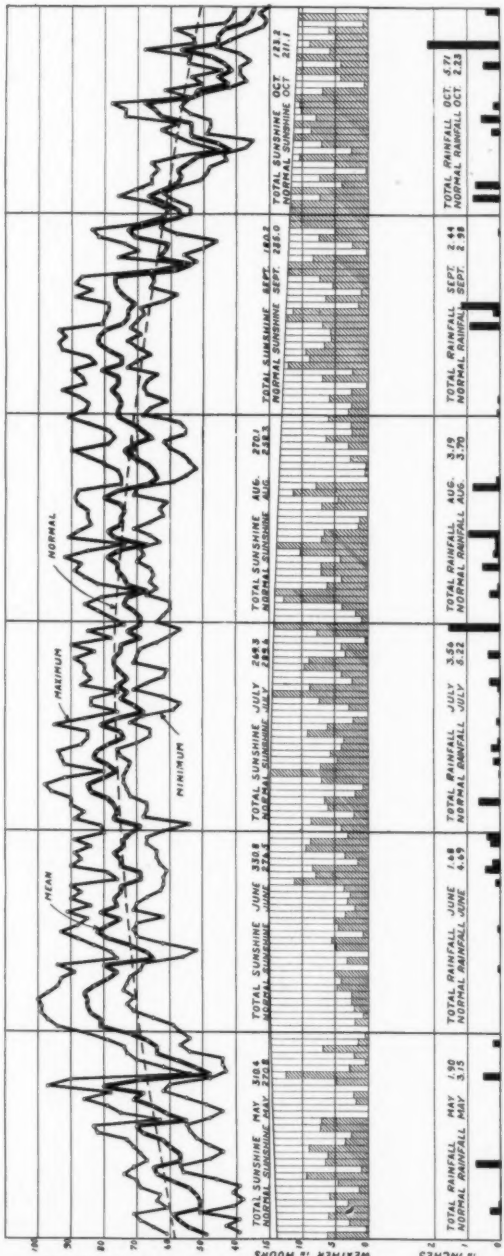

FIG. 1.—Climatic or meteorologic conditions under which corn of different varieties was grown at Arlington Experiment Farm, Rosslyn, Va., 1925

SEASONAL CONDITIONS

The seasonal climatic conditions under which the corn was grown are shown in Figure 1, which gives the meteorological data for the season of 1925 at the Arlington Experiment Farm.

Two outstanding features mark the season—an unusually long period of summer temperature and a considerable deficiency of rain during the growing season.

During the month of May the temperatures showed sharp fluctuations. On May 23, for instance, the summer temperature of 97° F. was recorded. Within 48 hours the maximum temperature dropped to 54°, a variation of 43°. During the latter part of May the temperature rose steadily, and on the 5th of June reached the highest maximum of the summer. The mean daily temperature for June was, with very few exceptions, above normal. During July it remained close to normal. It was slightly below normal during the latter half of the month and the early part of August. During August the temperature showed only slight variation from normal. Summer temperatures and almost unbroken summer conditions prevailed from June 1 to September 21. The latter part of September and the month of October showed the usual sharp fluctuations in temperature.

As already stated, the rainfall was below normal during the spring and early summer. The rainfall during May was only 60 per cent of normal. June showed the most pronounced shortage, the total for the month being 1.68 inches, or about 36 per cent of normal. In July the rainfall was 68 per cent of normal. Approximately one-half of this rain occurred on July 31. The rainfall for August and September was about normal in total amount, although the period from August 23 to September 13 was almost entirely rainless. October had more than twice its normal rainfall, the total for the month amounting to 5.71 inches. The sunshine for the entire season did not vary far from normal.

In the study of sweet-corn behavior it is important that seasonal conditions be taken into consideration since, as has been shown by the writers in an earlier study,[7] temperature has a profound effect upon the rate at which growth and maturity proceed, and influences to some extent also the relative proportions of the different chemical constituents in the kernel.

While rainfall has no apparent effect on the rate at which maturity advances or on the chemical composition of the corn, it does have a direct influence in determining crop yields. Indirectly, through its effect on soil temperatures, rainfall affects the vital processes in the corn kernels.

No specific effect of sunshine on sweet corn has as yet been discovered.

FLOWERING RECORDS

The flour corns, Mandan White and Yellow Assiniboine, were the first to reach the silking period, and the records of these two varieties were entirely similar. Silks were first observed on July 7, 52 days after planting. The silking continued over a period of approximately two weeks, although in both cases the peak of silking occurred on July 8.

[7] Magoon C. A., and Culpepper, C. W. Op. cit.

The flint varieties, Rhode Island White and Longfellow, were next to flower. Tasseling began on July 13, and on July 17, 62 days after planting, the first silks appeared. The peak of silking in the Longfellow was reached on July 26 and in Rhode Island White on July 28. Silking extended over a period of about three weeks.

The Guatemalan sweet variety began to tassel on July 20, and the first silks appeared on July 30, 75 days after the date of planting. Silking continued for about four weeks, the nearest approach to a peak occuring on or about August 16.

The plot of waxy maize began tasseling on July 21. The first silks were observed on August 9, 85 days from the date of planting. Silking continued for about three weeks, the peak being reached on August 20.

Second Early Adams, Golden Bantam, and Stowell's Evergreen, planted 41 days later than the varieties just mentioned, came into flower very much later than they would have if planted at the same time as the others. Second Early Adams and Golden Bantam each began tasseling on August 5. Their first silks appeared on August 11, 46 days after planting. Silking records were continued for a period of only two weeks. The peak of silking for Golden Bantam was reached on August 19, and for Second Early Adams August 20.

Stowell's Evergreen began tasseling on August 11. Silking started on August 19, 54 days from the date of planting. Records were discontinued after 17 days of silking, the peak being reached on August 31.

While the last three mentioned varieties were planted later and came to flower at a later date than the other varieties, it is doubtful if the actual length of time required for them to come to flower was very different from what it would have been had they been planted at the same time as the others. This assumption is based primarily on the fact that the temperature of the growing periods of both groups of corn as shown in Figure 1 was remarkably uniform.

The ear and cut corn records made in connection with the experiment under discussion are presented in Table 1.

TABLE 1.—*Rate of development of ears of different types and varieties of corn grown at the Arlington Experiment Farm, Rosslyn, Va., 1925*

Type or variety	Date of sampling	Age in days	Number of ears taken	Average weight of ears in grams	Average weight of husked ears in grams	Average weight of cut corn per ear in grams	Per cent of husk	Per cent of cob	Per cent of cut corn	Remarks
Mandan White (flour)	July 24	6	8	82.7	30.0	12.5	63.7	21.1	15.2	
	July 24	10	10	142.2	76.0	14.8	46.5	43.0	10.5	
	July 30	15	3	155.0	100.8	58.3	35.0	27.4	37.6	
	July 29	20	7	189.2	125.7	74.3	33.5	27.1	39.4	
	Aug. 6	24	9	193.3	125.6	81.7	35.0	22.7	42.3	
	Aug. 10	30	8	193.7	140.6	86.2	27.4	28.0	44.6	
Yellow Assiniboine (flour)	July 24	6	7	81.0	25.7	10.0	68.3	19.4	12.3	
	July 24	10	7	109.2	61.7	10.0	43.5	47.3	9.2	Very poor pollination.
	July 30	15	1	215.0	130.0	70.0	39.5	27.8	32.7	
	July 29	20	7	185.7	109.9	62.1	40.8	25.7	33.5	
	Aug. 6	24	8	177.5	113.7	73.7	35.9	22.5	41.6	
	Aug. 10	30	6	155.8	112.5	58.3	27.7	34.7	37.6	
Longfellow (flint)	July 27	5	13	159.6	55.8	14.5	65.0	25.9	9.1	
	Aug. 3	10	13	262.2	118.0	28.0	55.0	34.3	10.7	
	Aug. 7	15	6	286.6	155.8	41.6	45.9	39.8	14.3	
	Aug. 14	20	5	420.0	232.0	102.0	44.7	30.9	24.4	
	Aug. 24	25	8	326.1	196.8	110.6	39.6	26.4	34.0	
	Aug. 28	30	7	334.2	218.5	140.7	34.6	23.2	42.2	
Rhode Island White (flint)	July 28	5	14	148.5	45.7	16.8	69.2	19.4	11.4	
	Aug. 3	10	11	178.1	136.7	25.4	23.2	62.4	14.4	
	Aug. 12	15	10	261.5	156.0	42.5	40.3	43.4	16.3	
	Aug. 14	20	5	388.0	240.0	112.0	38.1	32.9	29.0	
	Aug. 24	25	8	324.5	219.9	126.2	32.2	28.8	39.0	
	Aug. 28	30	7	378.5	245.7	151.4	35.0	24.9	40.1	
Guatemalan (sweet)	Aug. 13	5	8	165.0	62.5	25.0	62.1	22.7	15.2	
	Aug. 13	10	6	190.0	95.9	20.9	49.4	39.9	10.7	
	Aug. 25	15	7	315.0	152.1	70.7	51.7	25.8	22.5	Scanty husks.
	Sept. 1	20	7	278.5	217.1	157.8	22.0	21.2	56.8	
	Sept. 9	25	7	308.5	182.8	117.1	40.7	21.2	38.1	
	Sept. 17	30	3	295.0	251.7	193.4	14.6	19.7	65.7	
Second Early Adams (dent)	Aug. 19	5	15	110.0	37.4	15.4	66.0	20.0	14.0	
	Aug. 25	10	10	171.0	86.0	26.0	49.7	35.0	15.3	
	Aug. 31	15	6	213.3	121.7	46.7	42.9	35.1	22.0	
	Sept. 9	20	7	300.0	191.4	104.3	36.2	29.0	34.8	
	Sept. 14	25	6	308.3	215.0	135.0	30.2	25.9	43.9	
	Sept. 17	30	6	315.8	226.7	145.9	28.2	25.5	46.3	
Waxy maize	Aug. 24	5	13	149.6	48.4	16.9	67.6	21.0	11.4	
	Aug. 24	10	8	192.5	68.8	21.3	64.2	24.6	11.2	
	Aug. 3	15	8	237.5	90.0	41.9	62.1	20.2	17.7	
	Sept. 9	20	9	276.6	116.6	71.1	57.8	16.4	25.8	
	Sept. 18	25	7	250.0	112.9	81.5	54.8	12.5	32.7	
	Sept. 21	30	6	201.6	128.3	102.5	36.3	12.8	50.9	
Golden Bantam (sweet)	Aug. 25	5	15	73.3	18.0	7.3	75.4	15.0	9.6	
	Aug. 25	10	13	120.7	52.2	26.9	56.7	20.9	22.4	
	Aug. 27	15	8	132.5	72.5	33.8	45.2	29.2	25.6	
	Aug. 31	20	7	148.5	91.4	52.9	38.3	26.1	35.6	
	Sept. 7	25	5	185.0	114.0	79.0	38.3	18.8	42.9	
	Sept. 16	30	5	168.0	113.0	81.0	32.6	19.0	48.4	
Stowell's Evergreen (sweet)	Sept. 5	10	8	236.2	115.0	38.8	51.3	32.2	16.5	
	Sept. 11	15	7	400.0	217.1	107.1	45.7	27.5	26.8	
	Sept. 14	20	5	518.0	358.0	214.0	30.8	27.9	41.3	
	Sept. 18	25	7	415.0	286.5	177.9	30.9	26.1	43.0	
	Sept. 28	31	5	540.0	400.0	284.0	25.9	21.4	52.7	

TESTS FOR TOUGHNESS

The results of tests of the corns for toughness at different stages of maturity are of considerable interest and are shown in graphic form in Figure 2.

It will be observed that the different varieties formed two distinct groups with respect to toughness: (1) The flour, flint, and waxy varieties, which became extremely tough as maturing proceeded; and (2) the sweet varieties and Second Early Adams, a dent variety, none of which exceeded the 420-gram mark at 30 days of age.

The grouping of the Second Early Adams with the sweet varieties, in respect to tenderness, is of particular interest. This variety is really a field corn belonging to the dent group. In earliness it corresponds closely with Golden Bantam. This fact, together with its relative tenderness, probably accounts for its wide use in the roasting-ear trade.

It is of interest also to compare the toughness curves of the varieties shown in Figure 2 with those of the dent varieties, Boone County White and Reid Yellow Dent, which were presented in a previous paper,[8] and which show that these two varieties were also relatively tender up to 30 days of age. It is by no means certain that all flint, flour, and waxy varieties are extremely tough or that all dents are relatively tender, even though records so far obtained indicate that this is the case.

The significance of the results recorded in Figure 2 will be discussed in another section of this article.

CHEMICAL STUDIES

The chemical constituents of corn, their nature, relative proportions, and physical conditions within the kernel, determine to a very large degree the suitability of any corn for canning purposes. This is particularly true of the carbohydrates. Within this group of substances are to be found those which determine

[8] CULPEPPER, C. W., and MAGOON, C. A. Op. cit.

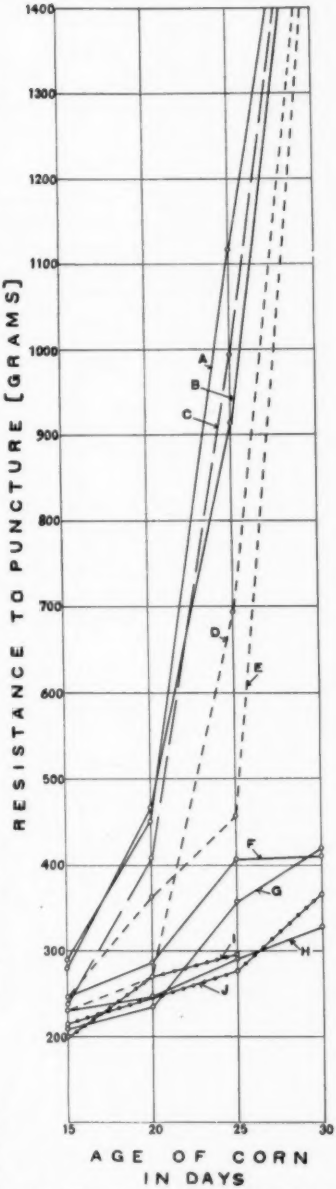

FIG. 2.—Degree and rate of increase in toughness of corn of different types and varieties with advancing maturity: A, Mandan White; B, Yellow Assiniboine; C, Waxy maize; D, Rhode Island White; E, Longfellow; F, Guatemalan; G, Stowell's Evergreen; H, Golden Bantam; I, Second Early Adams; J, Boone County White (from data collected in 1922 and introduced here for comparison)

the natural sweetness of the corn and the consistency and texture of the canned product.

The rôle of the nitrogenous constituents and of the oil of corn in their influence on quality is not known. It is possible that some of the distinctive flavors of corn of the different types and of corn at different stages of maturity are more or less closely associated with these substances. No investigation seems to have been made to determine such a relationship. The experiments covered by this paper did not include such a study. The presence of the distinctive fresh corn flavors and their rate of disappearance in the harvested corn seem to parallel closely the changes in sugar content.

The analytical data here presented, therefore, are concerned primarily with the carbohydrates of corn of the different types under investigation and the changes taking place in them as maturity advances.

It is a common notion that the property of sweetness distinguishes the so-called sweet corns from other types, making them better adapted to canning purposes, and that the accumulation of starch in the kernel is what gives to the corn in the can its desirable creamy consistency and texture. It has been shown by the writers,[9] however, that a relatively high sugar content is not confined to the sweet corns alone, and that the presence of dextrin or dextrinlike compounds in the sweet corns has much to do with the desirable physical properties of their canned product.

Among the different types of corn selected for the experiments here discussed a wide range of conditions, as regards the nature and relative proportions of the different carbohydrates, is known to exist. Waxy maize, for instance, has a very high dextrin content; the flint, flour, and dent varieties not only have high starch contents but the physical condition of the starch in the kernel differs greatly; and among the different types a considerable range in sugar content is found.

It is of interest, therefore, to follow the chemical transformations occurring in these different corns and to correlate the findings with those of practical canning tests. The analytical data are presented in Table 2 and are illustrated graphically in Figures 3 to 6, inclusive.

In the consideration of these figures and the following discussion of them it must be borne in mind that only a few varieties of the different types of corn have been included in the present experiments. The conclusions drawn from these results, therefore, may be found untenable when a larger number of varieties have been studied.

[9] CULPEPPER, C. W., and MAGOON, C. A Op. cit.

TABLE 2.—*Percentage composition of corn of different types and varieties at different stages at maturity*

Type or variety	Stage of maturity in days	Total solids	Alcoholic extract	Residue	Sugars						Polysaccharides			
					Total		Reducing		Sucrose		Total		Water-soluble	
					Fresh-weight basis	Moisture-free basis	Fresh-weight basis	Moisture-free basis	Fresh-weight basis	Moisture-free basis	Fresh-weight basis	Moisture-free basis	Fresh-weight basis	Moisture-free basis
		Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Mandan White (flour)	5	11.68	6.68	5.00	4.87	41.70	3.55	30.40	1.32	11.30	2.16	18.49	0.21	1.80
	10	11.33	6.64	4.69	5.10	45.01	3.00	26.47	2.10	18.54	1.91	16.85	.21	1.85
	15	22.57	6.96	15.61	4.35	19.27	1.25	5.53	3.10	13.74	10.96	48.56	2.17	9.61
	20	37.68	5.62	32.06	3.08	8.17	.53	1.40	2.55	6.77	25.17	66.80	2.00	5.30
	25	44.31	4.72	39.59	1.56	3.96	.19	.48	1.37	3.48	27.91	71.00	1.28	3.25
	30	52.40	3.28	49.12	1.25	2.38	.15	.28	1.10	2.10	37.43	71.43	1.86	3.55
Yellow Assiniboine (flour)	5	12.35	7.84	4.51	5.40	43.72	4.02	32.55	1.38	11.17	1.89	15.30	.13	1.05
	10	12.18	7.12	5.06	5.08	41.54	2.76	22.66	2.32	18.88	2.08	17.07	.18	1.47
	15	21.97	7.72	14.25	5.20	23.66	1.41	6.41	3.79	17.25	8.90	40.51	1.13	5.14
	20	34.86	6.32	28.54	2.91	8.34	.59	1.69	2.32	6.65	21.66	62.13	1.22	3.50
	25	42.65	4.32	38.33	1.45	3.40	.19	.44	1.26	2.96	29.66	69.56	1.61	3.77
	30	48.75	3.92	44.83	1.35	2.76	.12	.24	1.23	2.52	35.06	71.92	1.38	2.83
Waxy maize	5	10.96	6.12	4.84	4.12	37.59	3.43	31.29	.69	6.30	2.12	19.34	.15	1.36
	10	12.95	7.40	5.55	5.31	41.00	3.58	27.79	1.73	13.21	2.41	18.61	.30	2.31
	15	22.33	8.26	14.07	5.51	24.67	2.17	9.71	3.34	14.96	9.10	40.75	2.11	9.44
	20	35.04	7.00	28.04	3.86	11.01	1.04	2.96	2.82	8.05	21.62	61.70	8.29	23.65
	25	47.82	5.98	41.84	2.55	5.33	.37	.77	2.18	4.56	33.26	69.55	3.97	8.30
	30	55.76	4.10	51.66	1.80	3.22	.24	.43	1.56	2.79	40.39	72.55	5.47	9.81
Rhode Island White (flint)	5	13.18	7.10	6.08	5.10	38.69	3.68	27.99	1.42	10.70	3.20	24.28	.25	1.89
	10	11.06	6.64	4.42	4.37	39.51	3.32	30.02	1.05	9.49	1.96	17.72	.21	1.90
	15	17.08	7.94	9.14	5.45	31.90	2.00	11.71	3.45	20.19	5.53	32.37	1.03	6.03
	20	27.86	6.56	21.30	3.44	12.34	.94	3.37	2.50	8.97	15.07	54.09	2.12	7.61
	25	40.60	7.10	33.50	3.20	7.88	.60	1.47	2.60	6.41	26.26	64.68	3.41	8.40
	30	51.00	4.82	46.18	2.24	4.39	.37	.72	1.87	3.67	35.14	68.90	2.86	5.61
Longfellow (flint)	5	12.43	6.66	5.77	4.46	35.88	3.25	26.14	1.21	9.74	3.15	25.34	.22	1.78
	10	11.68	6.32	5.36	4.16	35.61	3.06	26.19	1.10	9.42	2.38	20.37	.20	1.71
	15	16.87	6.94	9.93	4.19	24.83	1.67	9.89	2.52	14.94	6.11	36.21	.64	3.80
	20	25.27	6.96	18.31	3.82	15.11	1.09	4.31	2.73	10.80	14.00	55.40	2.37	9.37
	25	40.90	5.64	35.26	2.73	6.67	.47	1.15	2.26	5.52	27.18	66.45	3.06	7.48
	30	54.02	4.72	49.30	1.79	3.31	.17	.31	1.62	3.00	37.31	69.06	2.56	4.73
Second Early Adams (dent)	5	11.25	6.20	5.05	4.16	37.00	3.02	26.84	1.14	10.16	2.37	20.17	.17	1.51
	10	10.56	6.44	4.12	4.31	40.81	3.24	30.68	1.07	10.13	1.79	16.63	.13	1.23
	15	18.37	7.64	10.73	5.16	28.08	2.45	13.33	2.71	14.75	5.16	28.09	.83	4.51
	20	23.91	5.72	18.19	3.05	12.75	.76	3.17	2.29	9.58	13.73	57.38	2.16	9.03
	25	32.27	5.48	26.79	2.41	7.46	.46	1.42	1.95	6.04	21.05	65.23	1.25	3.87
	30	42.52	4.86	37.66	1.86	4.37	.23	.54	1.63	3.83	29.07	68.36	1.82	4.27
Guatemalan (sweet)	5	9.94	5.42	4.52	4.12	41.44	3.11	31.28	1.01	10.16	1.77	17.80	.15	1.51
	10	11.23	6.08	5.15	5.31	47.28	2.56	22.80	2.75	24.48	2.15	19.14	.23	2.05
	15	20.27	7.28	12.99	5.51	27.18	1.36	6.71	4.15	20.47	8.57	42.28	2.90	14.30
	20	29.39	6.84	22.55	3.82	13.00	.81	2.75	3.01	10.25	16.57	56.38	7.86	26.74
	25	36.82	6.00	30.82	2.55	6.92	.49	1.33	2.06	5.59	24.04	65.29	11.52	31.28
	30	44.26	4.86	39.40	1.80	4.06	.30	.67	1.50	3.39	29.27	65.90	12.60	28.46
Stowell's Evergreen (sweet)	5													
	10	10.84	6.30	4.54	4.39	40.50	2.78	25.64	1.61	14.86	1.86	17.16	.58	5.35
	15	16.05	8.32	7.73	6.51	40.56	1.94	12.08	4.57	28.48	4.69	29.22	1.85	11.52
	20	22.05	7.22	14.83	4.45	20.18	.84	3.80	3.61	16.38	10.90	49.07	6.67	30.24
	25	27.76	5.68	22.08	3.06	11.02	.62	2.23	2.44	8.79	17.13	61.70	9.27	33.39
	30	32.18	5.46	26.72	2.78	8.63	.63	1.95	2.15	6.68	20.89	64.91	12.18	37.84
Golden Bantam (sweet)	5	10.08	5.72	4.36	3.74	37.10	2.98	29.56	.76	7.54	1.43	14.18	.11	1.09
	10	10.14	5.98	4.16	3.95	38.95	3.14	30.96	.81	7.99	1.52	15.00	.11	1.08
	15	16.15	9.16	6.99	6.91	42.78	2.43	15.04	4.48	27.74	3.37	20.86	1.18	7.30
	20	24.24	7.98	16.26	5.45	22.49	1.38	5.69	4.07	16.80	11.96	49.34	6.83	28.17
	25	34.36	6.52	27.84	3.35	9.75	.59	1.71	2.76	8.04	21.38	62.28	11.67	33.96
	30	41.27	4.20	37.07	1.31	3.17	.37	.89	.94	2.28	27.43	66.49	12.67	30.70

FLOUR CORNS

The two varieties of flour corn used in these tests proved to be early, reaching the silking peak about 53 days from the date of planting and maturing very rapidly after pollination had taken place. It was unfortunate that a late variety was not included in this group.

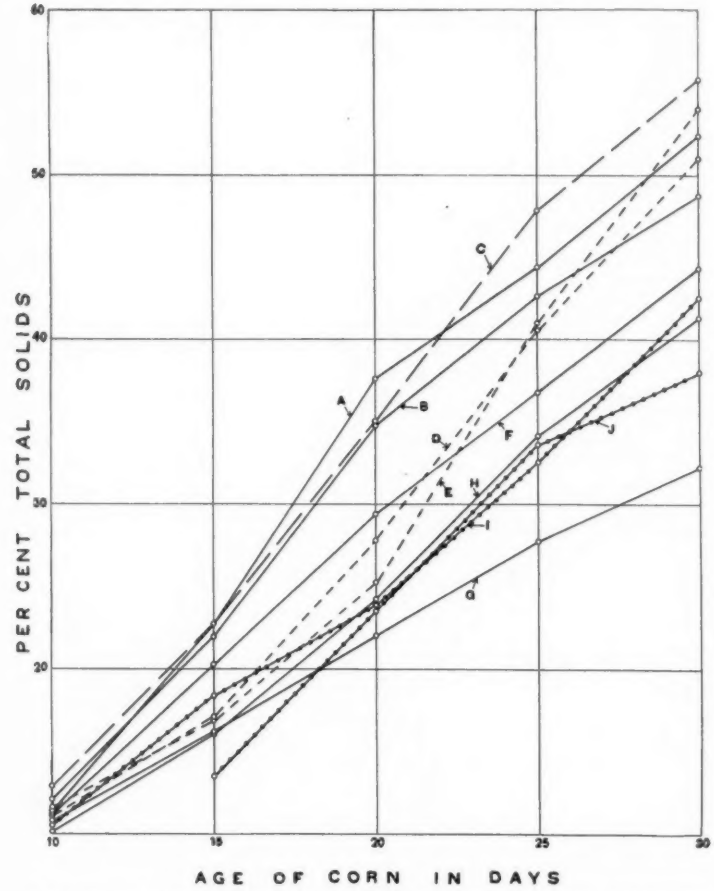

FIG. 3.—Degree and rate of increase in total solids in corn of different types and varieties with advancing maturity: A, Mandan White; B, Yellow Assiniboine; C, Waxy maize; D, Rhode Island White; E, Longfellow; F, Guatemalan; G, Stowell's Evergreen; H, Golden Bantam; I, Second Early Adams; J, Boone County White (from data collected in 1922 and introduced here for comparison)

As already pointed out, the flour type of corn is characterized by a soft, starchy endosperm, the cornaceous or flinty portion being very thin and inconspicuous. The floury character of the kernel contents, according to Weatherwax,[10] is due to the relatively small amount of

[10] WEATHERWAX, P. THE STORY OF THE MAIZE PLANT. 247 p., illus. Chicago, Ill. [1923].

protein or colloidal carbohydrate occupying the interspaces between the starch grains. The size and shape of the starch grains may also be in part responsible for the condition.

Examination of the analytical data shows that with respect to moisture content at the different stages of maturity the flour corns were lower than all the other varieties studied, except the flint corns at the 30-day stage, and the waxy maize, which the flour corns paralleled during the first 20 days of development and then exceeded in the later stages. The higher moisture content in the 25 and 30 day corn was due probably to the failure of the kernels to become as compactly filled as in the case of the waxy type.

The sugar content of the flour corns was lower than in the sweet corns, although the maximum attained was above 5 per cent. The decrease in amount was rapid after the 15-day stage and in the 25

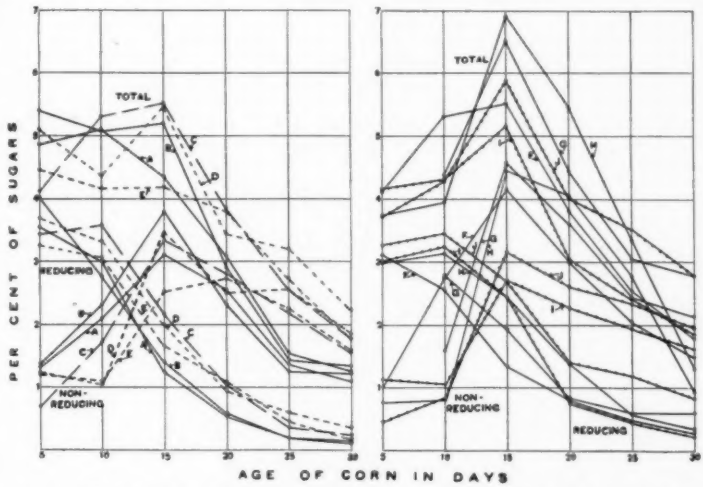

FIG. 4.—Sugar content of corn of different types and varieties at different stages of maturity: A, Mandan White; B, Yellow Assiniboine; C, Waxy maize; D, Rhode Island White; E, Longfellow; F, Guatemalan; G, Stowell's Evergreen; H, Golden Bantam; I, Second Early Adams; J, Boone County White (from data collected in 1922 and introduced here for comparison)

and 30 day corn the sugar content was lower than in any of the other varieties studied.

The water-soluble polysaccharides were very small in amount and did not increase significantly in the corn beyond the 15-day stage. The very low content of water-soluble polysaccharides in the later stages is particularly significant and helps to explain the floury character of the endosperm.

The percentage of total polysaccharides present in corn is determined to a large degree by the moisture content. The polysaccharides increase as the moisture content decreases and are less abundant where the moisture content is high. In the present case the proportion of polysaccharides also increased as the kernels became more mature. Considered from the moisture-free basis, the total polysaccharide content of these flour corns during the later stages was greater than in any of the varieties studied except waxy maize. This furnishes in part a chemical basis for their floury character.

WAXY MAIZE

Only one variety of waxy maize was available for these studies. Waxy maize is a very distinct type of corn, resembling in general form and appearance some of the flint varieties. The endosperm, however, on breaking has a waxlike appearance, which has given rise to the name applied to this type of corn. The waxy character applies to physical appearance only, the polysaccharide of which it is principally composed being erythro-dextrin, according to Weatherwax.[11]

This was the latest of the varieties studied. It required 96 days to reach the peak of silking and remained green for a considerable period.

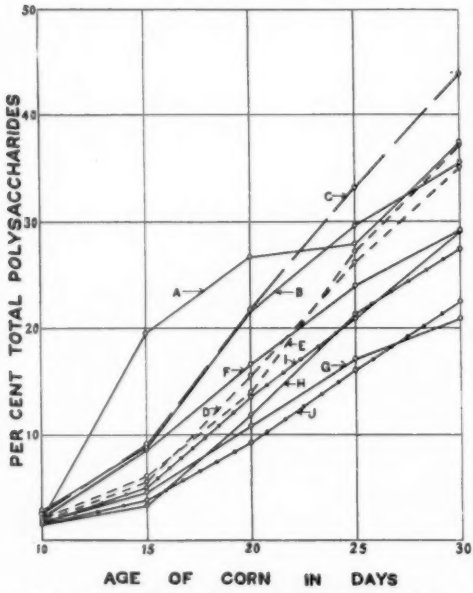

FIG. 5.—Degree and rate of increase in total polysaccharides in corn of different varieties with advancing maturity: A, Mandan White; B, Yellow Assiniboine; C, Waxy maize; D, Rhode Island White; E, Longfellow; F, Guatemalan; G, Stowell's Evergreen; H, Golden Bantam; I, Second Early Adams; J, Boone County White (from data collected in 1922 and introduced here for comparison)

The analytical data show a low moisture content throughout the entire period of development and maturing of the kernel. The moisture decreased continuously and rapidly up to 30 days from silking, when the amount present was slightly less than 45 per cent.

The polysaccharide total was very high, corresponding to the low moisture content, and consisted almost entirely of dextrin, as indicated by the iodine test. Its solubility, however, was entirely different from the ordinary dextrin, as a large proportion of it was insoluble in cold water. The water-soluble portion in the early stages of development was about the same or slightly greater in amount than in the sweet corns. In the waxy maize 25 and 30 days old, however, the proportion was very much less than in the sweet corns. This is very clearly shown in Figure 6.

The sugar content of waxy maize was somewhat lower than in Stowell's Evergreen and Golden Bantam, about equal to that of the flint varieties, and somewhat higher than in the flour corns and the dent variety, Second Early Adams. The total sugar content amounted to about 5½ per cent in the corn at the 15-day stage, but the ratio of reducing sugars to sucrose was high, indicating for the corn a degree of sweetness somewhat lower than the percentage of total sugars would ordinarily signify.

[11] WEATHERWAX, P. Op. cit.

FLINT CORNS

The two flint varieties used in these tests were typical of the New England grown corn of the flinty type, the hard, full, and well-rounded kernels of the mature corn being borne on long slender ears. In field behavior and in general appearance of the ears the two varieties tested were similar, differing only in the color of the grains.

These flint corns were medium late in maturing. It required about 73 days after planting for each to reach the silking peak.

According to Weatherwax,[12] the flinty or horny character of the endosperm in the flint corns is due to the presence in the cells of protein and colloidal carbohydrates which completely fill the interspaces between the starch grains.

The chemical analyses show that the flint corns in this case had a rather high moisture content during the early stages of development. As maturity advanced, however, the moisture content fell off rapidly, the corn 30 days old averaging lower in moisture even than the flour corns, and only about 3.2 per cent higher than waxy maize.

Figures 2, 3, and 4 indicate that during the early stages the flint corns developed somewhat more slowly than the flour corns and waxy maize, and therefore had a higher moisture content.

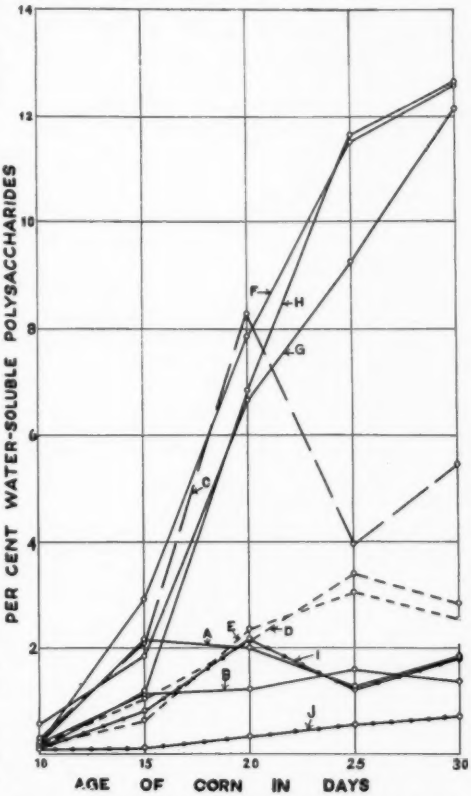

FIG. 6.—Variation in degree of water-soluble polysaccharides in corn of different types and varieties at different stages of maturity: A, Mandan White; B, Yellow Assiniboine; C, Waxy maize; D, Rhode Island White; E, Longfellow; F, Guatemalan; G, Stowell's Evergreen; H, Golden Bantam; I, Second Early Adams; J, Boone County White (from data collected in 1922 and introduced here for comparison)

The flint corns developed a somewhat greater proportion of water-soluble polysaccharides than the flour types, especially in the later stages of development, but they were far below the types of sweet corn in this respect. This is clearly shown in Figure 6. During the later stages of development the total polysaccharide content was higher in flint corns than in the sweet types, and averaged about

[12] WEATHERWAX, P. Op. cit.

the same as the flour types at the 30-day stage of maturity. In sugar content the flint corns were considerably lower than the sweet corns but higher than the flour corns, especially as maturity approached.

DENT CORNS

In the physical structure of the kernel the dent corns are intermediate between the flint and the flour types, the endosperm, as earlier pointed out, having two distinct portions, an outer horny or flinty portion and a central floury core extending to the tip of the grain. The shrinkage of this portion at the tip of the kernel as it dries out is what gives to it its dented form.

Only one representative of this group, Second Early Adams, was grown in the present case. This is a very early corn, requiring, under the present conditions, but 55 days after planting to reach the peak of silking. In this respect it compares favorably with Golden Bantam. Its earliness, tenderness, and other attractive qualities make it a favorite among truck-crop growers for the fresh-corn market.

In moisture content and in total polysaccharides, also, the Second Early Adams resembled Golden Bantam. In the proportion of water-soluble polysaccharides, however, this variety more closely resembled the flour corns, the amount present being small.

While a maximum total sugar content of a little over 5 per cent developed in the corn 15 days old, nearly one-half of the entire amount consisted of reducing sugars, indicating a corn low in sweetness. The sucrose present, however, did not disappear as rapidly as in the sweet varieties or the flour corns as maturity approached. In this respect Second Early Adams behaved like the flint and the waxy corns.

For the sake of a better understanding of the behavior of dent corns in general during the development and maturing of the kernel, reference is made to the results of similar tests upon two other dent varieties, Boone County White and Reid Yellow Dent, recorded in the earlier paper already mentioned.[13] While the percentages vary somewhat, the results obtained for these varieties show the same general trend as those given here for Second Early Adams. In the charts accompanying this discussion curves illustrating the findings on Boone County White in this earlier work have been included for comparison.

SWEET CORNS

The physical characteristics of the two sweet corns, Golden Bantam and Stowell's Evergreen, are too well known to require detailed consideration here. The story of their chemical behavior during the development and maturing of the kernel has already been told.[14] Under the conditions of the present season Golden Bantam required 54 days after planting to reach the silking peak, while Stowell's Evergreen, planted the same day, required 66 days to reach the same stage of development.

A third variety, which for lack of a definite name has been termed here "Guatemalan," was included in this group because it was known to be one of the very latest of the sweet type. In this case it required 92 days to reach the peak of silking.

The moisture content of these different varieties is of particular interest to the writers. In the earlier study, Golden Bantam, an early

[13] CULPEPPER, C. W., and MAGOON, C. A. Op. cit.
[14] MAGOON, C. A., and CULPEPPER, C. W. Op. cit.

variety, was found to have a relatively low moisture content, and Stowell's Evergreen, a late variety, was found to have a very high moisture content. The conclusion drawn from these earlier studies was that a close correlation exists between the moisture content and rate of maturing of the corn. The present study has confirmed the previous conclusions with regard to Golden Bantam and Stowell's Evergreen. When Guatemalan sweet was analyzed, however, it was found that instead of having a moisture content higher than that of Stowell's Evergreen, which required 66 days to reach the silking peak, its moisture content was actually considerably lower than that found in Golden Bantam, which required 54 days to reach the silking peak. Since, as already mentioned, Guatemalan required 92 days to reach the peak of silking, it is evident that the moisture content is a specific characteristic of the variety and is more or less independent of the rate at which the corn matures.

As a group, the sweet corns, together with the dent corn, had a relatively high moisture content, particularly in the later stages of maturity.

The outstanding features in the chemical composition of the sweet corns were a relatively high sugar content and a high percentage of water-soluble polysaccharides, consisting of dextrin and soluble starch. In the case of the Guatemalan sweet the maximum sugar content was 5½ per cent, which point was also equaled or approached by several of the nonsweet corns; but the percentage of sucrose in Guatemalan was higher than in any of these.

With but one exception—that of the Guatemalan sweet in its early stages of development—the sweet corns were lower in total polysaccharides throughout their entire development than the flour, flint, and waxy corns.

Taking into consideration these carbohydrate relationships, it would appear that among the flour, flint, and waxy corns there is a greater tendency for the sugars to be completely converted into starch than in the sweet and dent corns. On the other hand, the metabolic processes by which the sugars are converted into starch are partially arrested in the last-mentioned types, permitting an accumulation of sugar, but resulting ultimately in a lower polysaccharide content. In the flints and in the horny portions of the dent corns the starch grains seem to be embedded in a matrix consisting largely of soluble starch, while in the flour corns and the floury portion of the dent endosperm this matrix seems to be almost entirely absent. In the sweet corns a large amount of dextrin and soluble starch forms the matrix for the relatively few starch grains. This gives to the sweet-corn kernel its translucent endosperm. It is the loss of water by the endosperm in drying that causes the wrinkling of the grain.

CANNING TESTS

In order to observe the effect of the physical and chemical properties of corn of the types herein discussed on the quality of the canned corn, sample lots of ears were harvested from the different varieties, at the 20-day stage of maturity, and sample packs prepared from each. The canning methods employed were the same for all varieties, so that the canned products were strictly comparable. At the end of the season and at irregular intervals thereafter sample cans from the various lots were opened and the products subjected to careful comparative study. The results of these tests are presented below.

SWEET CORNS

The canned products from the Golden Bantam and Stowell's Evergreen were characteristic for these varieties and did not differ from those previously described.[15, 16] They were tender, of good texture and creamy consistency, sweet, and well flavored. They easily graded as first-quality products.

The canned corn from the Guatemalan sweet was somewhat poorer in quality. It was not so tender, the consistency was heavier, and it was less sweet. It was apparent that toughness was responsible to a considerable extent for the poorer product obtained from this variety.

These findings were in accord with the results of the chemical analyses and the earlier tests for toughness. Figure 2 shows that the puncture-test readings for Guatemalan sweet were considerably above those for Golden Bantam and Stowell's Evergreen. Table 2 and Figures 3 and 4, on the other hand, indicate that Guatemalan was lower in moisture content and in sugar than either of the other varieties. The puncture tests on the raw corn provided an accurate index of the tenderness of the corn in the can, while the moisture content was reflected directly in the consistency of the canned product.

FLOUR CORNS

The canned products from the two varieties of flour corns were similar in all respects. They were hard and tough, dry, and lacking in sweetness, and instead of the desirable flavor characteristic of sweet corn there was a hominylike taste which detracted from the quality. The creamy consistency observed in the products from the sweet varieties was entirely absent from the products of the flour types. These corns, therefore, were found to be wholly unsuited for canning purposes.

The two features most seriously affecting the quality in the flour corns were the extreme toughness of the kernel hulls and the hard, lumpy character of the kernel contents. Figure 2 shows that the pronounced toughness of the pericarp was foretold in the puncture tests, while a comparison of the chemical data on polysaccharides shows the reason for the hard and lumpy character of the product. In the case of the sweet varieties approximately one-half of the total polysaccharides were soluble in cold water. These gave to the canned product a creamy character, whereas in the flour corns only small quantities of water-soluble polysaccharides were present, the bulk of these being composed of starch which merely swelled during the canning process.

Water-soluble polysaccharides play a very important part in determining the quality of canned corn.

WAXY CORN

The canned product from waxy corn was likewise of poor quality. The kernel hulls were very tough, which detracted materially from the attractiveness of the corn. The product was rather dry in consistency. The kernel contents, while somewhat hard, were waxlike or

[15] CULPEPPER, C. W., and MAGOON, C. A. Op. cit.
[16] MAGOON, C. A., and CULPEPPER, C. W. Op. cit.

gummy rather than starchy in character. The corn was fairly sweet, but there was no distinctive flavor. This type of corn was decidedly unsuited for canning.

These findings have their confirmation and explanation in the physical and chemical data already presented. The puncture tests showed this variety to have a very tough pericarp. The low moisture content found accounts for the heavy consistency, while the mixture of nonsoluble and water-soluble dextrins explains the peculiar waxlike texture of the product.

FLINT CORNS

The canned material from the flint varieties, although not quite so dry, resembled in physical appearance the product from the flour corns. The hulls present were tough and the kernel contents hard and lumpy. It was lacking somewhat in sweetness, but the flavor was superior to that of flour corn. On the whole, the flint-corn product graded slightly higher than that from the flour corns but was far inferior to the product from the sweet varieties. The most objectionable features were the tough hulls and the hard kernel contents.

DENT CORN

The Second Early Adams was much more tender than any of the other field varieties. This tenderness was reflected in the quality of the canned product. In this respect it closely approached the sweet corns. The flavor and sweetness of the product were also very satisfactory. It lacked the smooth texture and creamy consistency characteristic of sweet corn, however, and the rather lumpy character of the kernel contents detracted from the quality of the canned material.

These findings agree well with those resulting from the puncture tests and the chemical analyses. The lack of creaminess finds its explanation in the low percentage of water-soluble polysaccharides in dent corn.

DISCUSSION

In the present work various types of corn have been studied and the possibility of their use for canning purposes has been discussed. The object of this investigation, however, was not so much to determine the merits of the different types for canning as to make through them an analysis of the factors which constitute what is termed "quality" in canned corn.

Two groups of factors influence quality in canned corn. One has to do with harvesting methods and cannery practices, and the other with the natural properties of the corn itself. It is the last-named factor with which this investigation is concerned. Of the factors included in this group may be mentioned the toughness of the pericarp, the consistency or creaminess of the kernel contents, the sugar content or sweetness, the moisture content, the compactness of the insoluble material in the endosperm, and the flavor.

The relative importance of any factor depends upon the degree of variation which occurs, the readiness with which it may be corrected by methods of handling, and the way it is affected by other existing factors. Thus, if sugar content is the only significantly variable factor, the variety having the highest sugar content is the most desirable; and if the outstanding variation is in the tenderness of the pericarp, that corn in which it is toughest is the least desirable.

A study of the types here discussed shows that the tenderness of the kernels varies widely, both with the degree of maturity and with the type of corn, as well as with the varieties within the types. The sugar content is quite variable in the different types and in the varieties within the types. It varies much more widely, however, with the degree of maturity. The texture and consistency of the canned product also is subject to considerable variation, the former with the type of corn used and the latter both with the type and the degree of maturity. Flavor is much less variable. Significant variations do occur, but the differences seem less objectionable than variations in tenderness. The significance of these factors will be discussed in greater detail in the following paragraphs.

TENDERNESS

The results of the experimental work reported above indicate clearly that of the inherent properties which affect the quality of canned corn, the degree of tenderness of the pericarp is most important. In measuring this degree of tenderness or toughness by mechanical means some slight error is involved because of the structure of the underlying tissues, which give support to the kernel hull. When the kernels are compactly filled with starch and dextrin, as in the corn at the more mature stages, the readings are correspondingly high. This is not an important consideration, however, for experience has shown that the puncture-test readings furnish a very reliable working index of the probable tenderness of the cut-out corn.

The quantity of the pericarp entering into the canned product has an effect on the apparent toughness or age of the corn. Thus, corn that is a little tough will appear more tender and less mature if it is double cut or slit and scraped than when canned in the so-called "Maryland style," where the kernels are practically whole.

The toughness of the pericarp is not noticeably affected by an increase in the processing period. Tough corn could not be made tender even if the objectionable features of overprocessing could be surmounted.

In general the field varieties are considerably tougher than the sweet varieties at comparable stages of maturity. This in large measure accounts for their being unsuited for canning purposes. The dent varieties used in these and preceding tests were found to be more tender than the other field types. Second Early Adams, belonging to this group, was about as satisfactory from this standpoint as Golden Bantam or either of the other sweet varieties.

The age of the corn, or its degree of maturity, determines very largely the degree of toughness of the kernel hull. The toughness increases steadily and, in many cases, rapidly as maturity approaches. Were it not for the fact that other factors besides toughness have to be taken into consideration in the grading of corn for canning, it could be harvested when young and tender. In very young corn, however, those constituents which give proper body or consistency to the canned product are lacking. Too often, therefore, tenderness is sacrificed to consistency.

It seems evident that the most satisfactory way to meet the requirements for tenderness is to can the corn at as early an age as the consistency of the kernel contents will permit, and to endeavor by selection and breeding to develop tenderer strains, so that more mature corn may be used without sacrifice of quality.

TEXTURE AND CONSISTENCY

Although the body or consistency of the kernel contents usually determines when the corn shall be harvested, the experiences of the present work have forced the conclusion that this factor holds second place in determining quality.

Two elements enter into the determination of consistency—the nature of the polysaccharides present and the moisture content. It will be recalled that about one-half of the total polysaccharides present in sweet corns at canning maturity are water-soluble, being in the form of dextrin or dextrinlike compounds. These are responsible for the creamy texture of the canned product and when combined with the proper amount of moisture give the desired body to the canned material. In order to get the proper consistency it is always necessary to add liquid to the cut-off corn. If too little liquid is added or the corn is too mature the finished product will be too dry or viscous. Regardless of how much or how little liquid is added to it, the canned product of very young corn will not be creamy, because sufficient polysaccharides have not been stored in the kernels.

The water-soluble polysaccharides are practically absent in all field varieties except the waxy corn. On account of the presence of starchy lumps the canned product from these varieties is more or less granular and the creamy texture is entirely lacking. While considerable quantities of water-soluble polysaccharides are present in the waxy maize, the remaining carbohydrate is so compactly stored in the kernel that the texture and consistency are unsatisfactory.

The consistency of canned corn is modified greatly by the method of cutting and by precooking. The fineness with which the corn is cut affects both the appearance of the pack and its consistency, and the product is given a smoother and more creamy texture by the agitation given to the corn in the precooker.

In Maryland-style corn where the kernels are removed from the ear nearly whole, a viscous or cloudy liquor is objectionable and consistency is of no consideration. "Blanching" corn on the cob prior to cutting, as is sometimes practiced by home canners, yields a product that is less creamy. This is accounted for primarily by the fact that the kernel contents are coagulated by the heat and less of the material passes out into the added liquid.

SUGAR CONTENT

Natural sweetness is next in order of importance among the factors affecting quality in canned corn. The sweetness is roughly proportional to the total quantity of sugar present. The quantity and relative proportions of the different groups of sugars in corn are constantly changing as development proceeds. At the time corn is ordinarily canned, sucrose, or cane sugar, is responsible for most of its natural sweetness. The ease with which deficiency in sweetness may be remedied by the addition of sucrose in the brine has raised some question as to whether natural sweetness is of much significance in corn. Sweet corns, as a rule, contain more sugar than the field varieties. In some cases, however, the difference is not great. Occasionally, also, where the sugar content is relatively low, other desirable features, such as tenderness, for instance, make the corn more acceptable than others having a higher sugar content. The present study indicates that natural sweetness is not often the deciding factor in the choice of the best type or the best variety of corn.

Corn containing 5½ per cent of sugar, or approximately the concentration normally present in corn at its highest sugar content point, is considered most desirable for the canned product. When corn is ready for canning it has passed somewhat beyond its highest point of sweetness, therefore it is necessary to add sucrose at the time of canning in order to obtain the most acceptable product. The quantity varies from 4 to 10 per cent in the brine, depending on the condition of the corn. The average brine contains about 6¼ per cent of sugar.

It is the opinion of some that added sugar fails to supply the quality of sweetness produced by the natural sugar of the corn. Lack of sugar, however, is nearly always associated with other objectionable properties in the corn, such as toughness, too heavy consistency, and poor flavor, so that it is questionable whether this opinion has much weight.

Since the percentage of sugar in any variety is constantly changing, it might be supposed that the stage of maturity at which the sugar content was highest would be optimum for canning. This is not the case. In the region of Washington, D. C., for instance, corn reaches its highest sugar content about 15 days after the first appearance of silks; but at this stage the corn, particularly of the late varieties, is much too immature to give desirable body and flavor.

High sugar content is desirable in corn for canning, and contributes much to the quality of the canned product,. Other factors, however, appear to be of considerably more importance.

FLAVOR

Sweetness in corn constitutes much of what the average person considers flavor. Experiments show that corn in prime canning condition which is canned without sugar lacks the flavor of corn canned with sugar. High sugar content, however, does not always mean high flavor or quality. In the present tests corn 15 days old from silk, though higher in sugar content than others more mature, was considered by nearly all judges as lacking in flavor. Just what chemical constituents are responsible for the pleasing characteristic flavor of prime sweet corn is not known.

Very small differences in flavor occur in varieties of the sweet type at comparable stages of maturity, such differences being more particularly marked between the white and the yellow varieties. The variations in flavors among the different types of corn are somewhat greater. Only in rare instances, however, are even these type differences considered of much importance.

As corn approaches maturity the pleasing flavor gradually disappears and is replaced by one considerably less attractive.

COMPACTNESS OF THE ENDOSPERM

As already suggested, a part of what is usually considered toughness is really due to the compactness of the endosperm. In the flint corns, and in the waxy type especially, the endosperm is very hard and compactly filled with carbohydrate. This becomes especially marked as the corn approaches maturity. The endosperm of the sweet varieties is much less compact than that of any other type. There is considerable variation among the sweet corns in this respect, as was shown by the Guatemalan sweet and Stowell's Ever-

green in the present tests. The kernels of the Guatemalan sweet were considerably more compactly filled than Stowell's Evergreen, as shown not only by physical appearance but also by their lower moisture content.

As affecting the quality of the product from the varieties usually canned this factor probably is not of much significance.

CELLULAR STRUCTURE

No histological studies were made of the different types of corn used in these tests. The readiness with which the contents of the kernels of some of the sweet varieties escaped into the liquid during the canning process, however, suggests that there may be some marked difference in the cellular structure. Size of the cells or thickness of the cell walls may vary considerably in the different types and varieties and may have some influence on the quality of the canned material obtained from the different corns.

SUMMARY

Several types of maize have been studied with respect to the degree of toughness of the pericarp, the chemical composition of the kernels, and the canning quality of the different types.

There is great variation in the different types and in all types at different stages of maturity in the toughness of the pericarp. The degree of toughness is much greater in the flour, flint, and waxy types than in the dent and sweet corns. This toughness is particularly marked with the approach of complete maturity.

The most characteristic difference in chemical composition is found in the content of water-soluble polysaccharides. The sweet corns have a very high proportion of this constituent. It is relatively high also in the waxy maize but rather low in the flint, dent, and flour types.

There is a very significant difference in the various types as well as in varieties of the same type in the moisture content of the developing kernels. This difference generally becomes more marked as maturity approaches.

In general, the sugar content is higher in the sweet varieties than in the other types, but the differences are not so marked as might be expected, in view of the preference generally shown to sweet corn for table purposes.

In tests upon the relative quality of the different types for canning purposes the sweet corns were found superior to all other types, followed in order by the dent, waxy, flint, and flour types.

From a study of the data here presented it is possible to list the following as factors which are preeminent in determining the quality of the canned product:

1. The degree of tenderness or toughness of the pericarp.
2. The nature of the polysaccharides present, and the ratio of water-soluble to total polysaccharides.
3. The sugar content.
4. The compactness with which the polysaccharides are laid down in the endosperm, and possibly the cellular structure of the endosperm itself.

RELATION OF SOIL TEMPERATURE AND SOIL MOISTURE TO THE INFECTION OF SWEET POTATOES BY THE STEM-ROT ORGANISMS[1]

By L. L. HARTER, *Pathologist*, and W. A. WHITNEY, *Junior Pathologist, Office of Vegetable and Forage Diseases, Bureau of Plant Industry, United States Department of Agriculture*

INTRODUCTION

The relation of soil temperature and soil moisture to the infection of different crops by parasitic fungi has been investigated by a number of workers. Monteith [2] showed that soil temperature was not a limiting factor in the infection of cabbage by *Plasmodiophora brassicae* Wor., since infection occurred at widely different temperatures. Soil moisture, on the other hand, was found to be important. Gilman [3] showed that infection of cabbage by *Fusarium conglutinans* Woll., the organism causing yellows, occurred only at relatively high temperatures, which would indicate that the most severe development of the disease might be expected during seasons in which high temperatures prevailed in the early part of the growing period. Jones, McKinney, and Fellows [4] found that infection of potatoes by the scab organism, *Actinomyces scabies* (Thaxt.) Güssow, is favored by relatively high temperatures, and Tisdale [5] demonstrated that there is a close correlation between the temperatures at which *Fusarium lini* Bolley grows best in pure culture and those at which flax wilt is most destructive.

Sweet potatoes (*Ipomoea batatas* Poir.) are affected by several soil-inhabiting organisms—*Ceratostomella fimbriata* (E. and H.) Ell., the cause of black rot; *Monilochaetes infuscans* Ell. and Hals., the scurf organism; *Fusarium batatatis* Woll., and *F. hyperoxysporum* Woll., the stem-rot organisms; and others. Judging from the amount of infection that occurs in some seasons, there are grounds for believing that the severity of some of these diseases is fundamentally correlated with environmental conditions such as soil moisture and soil temperature.

Poole [6] grew sweet potatoes in pox-infested soils of different water content and found that abundant infection occurred only when it was dry and that no infection occurred in wet soils. Harter and Whitney [7] demonstrated that soil moisture is not a limiting factor in infection by the black-rot organism, *Ceratostomella fimbriata*, inasmuch as infection would occur at any moisture content permitting the growth of the plants. So far as temperature is concerned, however,

[1] Received for publication Oct. 19, 1926; issued April, 1927.

[2] MONTEITH, J., JR. RELATION OF SOIL TEMPERATURE AND SOIL MOISTURE TO INFECTION BY PLASMODIOPHORA BRASSICAE. Jour. Agr. Research 28: 549–562, illus. 1924.

[3] GILMAN, J. C. CABBAGE YELLOWS AND THE RELATION OF TEMPERATURE TO ITS OCCURRENCE. Ann. Missouri Bot. Gard. 3: 25–84, illus. 1916.

[4] JONES, L. R., MCKINNEY, H. H., and FELLOWS, H. THE INFLUENCE OF SOIL TEMPERATURE ON POTATO SCAB. Wis. Agr. Expt. Sta. Research Bul. 53, 35 p., illus. 1922.

[5] TISDALE, W. H. RELATION OF TEMPERATURE TO THE GROWTH AND INFECTING POWER OF FUSARIUM LINI. Phytopathology 7: 356–360, illus. 1917.

[6] POOLE, R. F. THE RELATION OF SOIL MOISTURE TO THE POX OR GROUND ROT DISEASE OF SWEET POTATOES. Phytopathology 15: 287–293, illus. 1925.

[7] HARTER, L. L., and WHITNEY, W. A. INFLUENCE OF SOIL TEMPERATURE AND SOIL MOISTURE ON THE INFECTION OF SWEET POTATOES BY THE BLACK-ROT FUNGUS. Jour. Agr. Research 32: 1153–1160, illus. 1926.

it was found that the optimum for the growth of the plants is higher than the maximum at which infection would occur.

Among the diseases of the sweet potato, stem rot is one whose seasonal prevalence and severity seem particularly closely correlated with soil conditions. This disease, which is caused by two species of Fusarium—*F. batatatis* and *F. hyperoxysporum*—appears to be most severe when the weather is very warm and the soil relatively dry during the early part of the growing season.

In order to determine what influence, if any, soil moisture and soil temperature had on infection, an effort was made to control these factors experimentally.

METHODS

TANKS

In these experiments 12 of the so-called "Wisconsin temperature tanks" were used. Each was equipped with an electric control and could be maintained at any temperature desired above 10° C. Inasmuch as most of the investigations were conducted during warm weather, a propeller was installed in each tank to prevent the accumulation of a stratum of warm water at the surface. Notwithstanding this precaution, the temperature varied somewhat from day to day, but any large fluctuations were prevented by the addition of heat or of cold water as necessity required.

The tanks were located in a greenhouse in which there was somewhat less light than would be expected under field conditions. The temperature of the greenhouse ranged from 50° to 85° F. in the daytime and from 60° to 70° at night, depending on the season of the year.

SOIL

The soil employed was a fine sandy loam containing a considerable amount of silt and small gravel and was rather low in organic matter. It was obtained from a low part of the Arlington Experiment Farm at Rosslyn, Va., on which several crops had been grown, and, on the whole, it was well suited for sweet potato culture. Before being used the soil was sifted to remove the gravel and undecayed vegetable matter and was then sterilized by steam for seven hours at 15 pounds pressure. An equal quantity of soil (usually 3,650 gm.) was placed in each can of a given series in all the experiments.

The relation of soil moisture to infection was studied by varying the water content in the soil, the temperature being kept constant. The soil had a water-holding capacity of 25.4 per cent, a moisture equivalent of 9, and a wilting coefficient of 4.9. The soil moisture was calculated in percentage of its water-holding capacity. In the soil-moisture experiments water was added from time to time. It is obvious, however, that such a procedure would of necessity give questionable results, since no method has yet been developed whereby water can be added uniformly to all parts of the soil.

In studying the influence of temperature on infection, the temperatures were varied and the amount of water in the soil kept constant. At frequent intervals, usually once each day, water was added to the cans to restore them to their original weight. A ½-inch glass tube was inserted about 5 inches into the soil, and through it water was delivered to the interior of the can. Again the objection may be

raised that the water was not uniformly distributed throughout the soil. In this case, however, the water relations were not being studied.

The same soil was used in the different series of experiments. At the close of each experiment it was removed from the cans and both the cans and the soil were sterilized by steam for seven hours at 15 pounds pressure, after which the soil was sifted to remove the roots and any other coarse matter that might affect the results. After the soil was thoroughly mixed a weighed portion was added to each can, together with enough water to bring it up to the desired soil-moisture content.

HOST

The Yellow Jersey, one of the sweet potato varieties most susceptible to stem rot, was used in all the experiments. This variety is popular in some of the northern markets and is extensively grown in the States along the northern border of the sweet-potato belt. Disease-free sweet potatoes were bedded in sand containing a small quantity of silt, and when the sprouts reached a height of 6 to 8 inches they were pulled and the roots immersed in a spore suspension of the stem-rot organisms and set out, two or three plants in a can.

MOISTURE

In the experiments to determine the influence of temperature on infection a fairly high moisture content of the soil was maintained, but when the study of the influence of soil moisture on infection was made, the methods were somewhat altered. The quantity of moisture in the soil ranged from very dry to supersaturation. When very dry soil was used the carrying over of a small amount of water on the roots of the plants to the soil might be expected to alter the results materially. Furthermore, spores suspended in water on the roots might conceivably find a more congenial condition for germination and infection. For these reasons the water was allowed to dry off before the plants were set.

PATHOGENE

The organisms employed in these investigations were isolated from sweet potatoes from various parts of the United States, some of which had been carried in cultures for a number of years. No special care was exercised to maintain the organism in what is called "high cultures" and, for the most part, it was not so maintained. In only a few cases were sporodochia present and in no case pionnotes, there being a preponderance of one-celled spores. The cultures were transferred at frequent intervals, usually to stems of *Melilotus alba* Desc. When infection experiments were to be made, the cultures were removed from the tubes and washed in a vessel of water in which the roots were immersed.

TEST OF INFECTION

Investigators familiar with infection experiments of this type will realize the difficulty of determining with certainty when infection has actually taken place. A border line is frequently found where the judgment of the observer must prevail. Typical cases of infection are easy to diagnose, but the nontypical ones which are frequently met under abnormal environmental conditions are sometimes baffling. In the experiments here reported most of the infected plants

could be detected easily. Infection was apparent on most of the plants in about five days. Those which showed unmistakable infection were pulled up, carefully examined, and recorded. At the close of the experiment all the plants remaining in the cans were carefully removed, the roots washed free of soil, and then examined for stem rot. When no external symptoms of disease were apparent the stem and roots were carefully split open and the fibrovascular bundles examined for evidence of blackening. A number of plants were found with bundles blackened from the roots to the stem which still showed no evidence of disease on the foliage and little if any reduction in vigor. In view of these facts it was finally concluded to classify as infected all plants which showed any blackening of the fibrovascular bundles regardless of whether they exhibited any external symptoms.

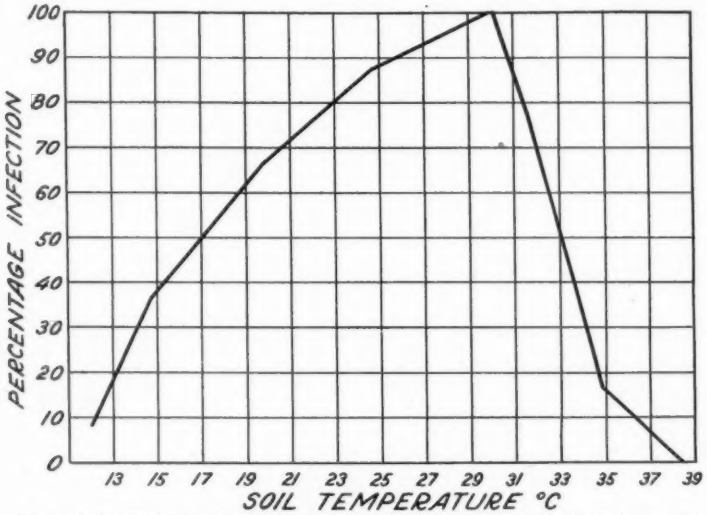

FIG. 1.—Influence of soil temperature on the infection of sweet potatoes by the stem-rot organisms

RELATION OF SOIL TEMPERATURE TO INFECTION

In all, nine experiments were conducted to determine the relation of temperature to infection, but of these only the last six were employed in the construction of Figure 1. The first three were regarded as merely preliminary, and were planned to determine the optimum soil moisture for growth and to test the efficacy of the method, the virulence of the organisms, and the reliability of the mechanical equipment. While sweet potatoes will grow within a wide range of soil moistures, the best growth was made at about 60 per cent of the water-holding capacity of the soil, and approximately this amount was employed in all except the preliminary experiments. The conclusions as to what constitutes the minimum, optimum, and maximum temperatures for growth are drawn from the combined results of six separate experiments and are shown in Figure 1. It will be seen that a small percentage of plants was infected at a temperature of 12° C. It is interesting to note in this connection that sweet

potatoes will not survive a temperature of 12°, for at this temperature the plants gradually die. The optimum for infection was found to be approximately 30° and the maximum nearly 35°, the optimum for infection being lower than the optimum for the growth of the plant. As a matter of fact, the optimum temperature for the growth of sweet potatoes is very near the maximum for infection, or approximately 35°. The maximum for the growth of sweet potatoes is certainly above 38° and well above the maximum temperature for infection.

RELATION OF SOIL MOISTURE TO INFECTION

Field observations indicate that stem rot causes much greater loss during a dry season than during a wet one, particularly if the weather is dry for a few weeks immediately after planting. Whether this is due to the greater number of infections during a dry season or to the fact that diseased plants are more apt to succumb during periods of drought has not been determined. Inasmuch as no data were available to explain the influence of soil moisture on infection, a series of experiments was outlined to establish within reasonable limits the minimum, optimum, and maximum quantity for infection. Two methods of procedure were tried. Soil cultures were made up in steps of 10 from approximately 10 to 100 per cent of its water-holding capacity. The temperature of the pots was held near 30° C., although there was some fluctuation. The actual water-holding capacity of the soil was determined at the beginning and at the close of the experiment. In both methods the sprouts were dipped in a spore suspension of the stem-rot organisms, planted, and the surface of the soil covered with about one-half inch of ground cork to reduce the loss of water from evaporation. By the first method no more water was to be added to the plants during the entire course of the experiment. The data obtained by the use of this method were considered practically valueless, since the time required to obtain results was so long that the soils of greatest water content had so dried out that they contained about the same quantity of moisture as the dry ones.

By the second method enough water was added daily to bring the pots to their original weight. At the end of the experiments the soil was removed from the pots and examined. From these examinations it was noted that the moister soil was either near the surface and out of reach of the roots or in isolated spots. The soil in the bottom of the pots was very dry. Figure 2, drawn from the data of two experiments in which the second method was used, shows the results obtained. The water-holding capacity of the soils, which were thoroughly mixed before the samples were taken, was found at the close of the experiment to be approximately the same as at the beginning. However, the roots were in a much drier soil, so that the results, if based on the water-holding capacity of the soils, are unreliable. The results show a high percentage of infection over a wide range of soil-moisture conditions, while as a matter of fact the roots were subjected to about the same moisture content—i. e., a fairly dry soil.

Although the data do not give a true picture of the influence of different quantities of soil moisture on infection, they do show that infection will take place in a soil containing only enough moisture to support plant growth. A soil containing moisture equivalent to 14 per cent of its water-holding capacity would not support the growth

of plants, and no infection took place. At 23 per cent of the water-holding capacity of the soil, plant growth was barely supported and 11 per cent of the plants were infected, while at a soil moisture of 28 and 75 per cent with normal plant growth, 94 and 100 per cent infection, respectively, resulted.

Some difficulty was experienced in determining infection in saturated and supersaturated soil because of the fact that the plants rotted below the soil line. Under these conditions some blackening of the fibrovascular bundles in the underground part of the stem resulted, and occasionally the blackening extended into the aerial portions of the stem. Hence, the 45 per cent infection in supersaturated soil, shown in Figure 2, may or may not have been caused by the stem-rot organism, especially since a similar condition occurred in some of the control plants.

METHOD OF INFECTION

In conjunction with the soil-moisture and soil-temperature studies some related problems were investigated, the results of which can be presented appropriately at this point. As a result of field observations it is generally admitted that a large number of stem-rot infections take place in the field. The correctness of these observations has been demonstrated by greenhouse experiments with infested soil. In the study of the relation of temperature to infection the plants were dipped in a spore suspension and then planted in disease-free soil. At the termination of some of these experiments healthy plants were set in the pots from which diseased plants had been removed. Out of a total of 34 plants treated in this manner 6 became infected, that is, about 18 per cent. The plants employed in these experiments were wounded at the point where they were pulled from the mother potato, and such wounding no doubt contributed to the ease of infection.

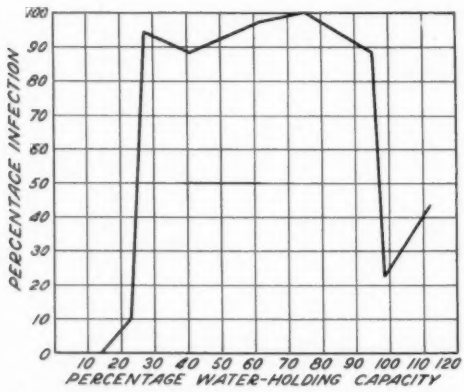

FIG. 2.—Influence of soil moisture on the infection of sweet potatoes by the stem-rot organisms

Considerable doubt has existed in the minds of some investigators as to whether wounding is necessary for infection. To obtain information on this point two groups of experiments were conducted in the greenhouse in sterilized soil at a constant soil temperature of 30° C. The excessive loss of water by evaporation was reduced to a minimum by covering the soil in each pot with 35 gm. of ground cork and the ratio of water to soil was kept constant by the daily addition of water. The sweet potatoes (Yellow Jersey) were sound, smooth, and free from disease and would be considered excellent seed. The potatoes were dipped in a spore suspension of the stem-rot organisms

made from several different isolations. The conditions being excellent for sprouting, the first plants appeared above the ground in about five days in both inoculated and control pots.

In the first group of experiments the sprouts were left attached to the potato until the conclusion of the test, when they were all removed and examined for stem rot. In the three experiments of this kind 469 plants were produced on 33 potatoes and a total of 9 diseased plants was observed. The lowest percentage of infection for a single experiment was 0.49 and the highest 5. The second group of experiments was similar in all respects to the first except that at the end of a certain time the plants were pulled from the mother potato and set out in a plant bed. Twenty-seven days after bedding the plants had attained considerable size, but no infection was apparent. Forty-one of these plants were then pulled and set in sterilized sandy loam for further study. Thirteen days later some showed unmistakable symptoms of stem rot. Others became diseased from time to time, until after the plants had been placed in soil 25 days, when the experiment terminated, all but 12, or practically 71 per cent, showed evidence of disease.

The effect of pulling plants from the mother potato on the infection of those remaining may be inferred from the following data: 11 days after the 41 plants referred to above were removed infection was noted in some of those remaining, and 7 days later 26 out of a total of 138 plants were diseased. These results seem to indicate that as long as plants are attached to the mother potato they will not become generally infected, but that as soon as a wound is made by pulling off a sprout, infection will occur.

Free-hand sections of several of the mother potatoes showed that the stem-rot organism which entered at wounds made by pulling off the sprouts had traversed the fibrovascular bundles as far as 3 cm. from the point of entrance. Some of the sprouts in communication with these fibrovascular bundles were infected therefrom.

SUMMARY

Experiments conducted in the greenhouse to determine the relationship between the temperature of the soil and the infection of sweet potatoes by the stem-rot organisms, *Fusarium hyperoxysporum* and *F. batatatis*, showed that the optimum temperature for infection is about 30° C. and the maximum about 35° C. The minimum could only be approximated, since infection occurred at a temperature as low as that at which the plant would grow.

The influence of soil moisture on infection was more difficult to determine. Infection was found, however, to occur over a wide range of soil humidity. At 28 and 75 per cent of the water-holding capacity of the soil 94 and 100 per cent, respectively, of the plants became diseased. Infection also took place in a soil containing only enough moisture to support plant growth.

Healthy plants set in infested soil may become diseased. Wounding is not necessary to infection but increases it. A small percentage of sprouts from healthy potatoes dipped in a spore suspension of the causal organisms became infected. The percentage of infection, however, was greatly increased when the sprouts were pulled, both in those that were pulled and in those that remained.

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A TRANSIT DISEASE OF SNAP BEANS CAUSED BY PYTHIUM APHANIDERMATUM[1]

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INTRODUCTION

Species of Rhizoctonia, Sclerotinia, Botrytis, and Rhizopus are frequently associated with, and are unquestionably largely responsible for, a major portion of the losses of snap beans (*Phaseolus vulgaris* Linn.) in transit and on the market. Ramsey [2] has shown that beans may be decayed by *Sclerotinia sclerotiorum* (Lib.) Massee, *S. intermedia* Ramsey, and *S. minor* Jagger, all of which produce a characteristic watery soft rot. The seriousness of the loss in transit caused by Sclerotinia may be inferred from the following quotation from Ramsey's paper:

> After selecting at random 42 cars of green beans, which on inspection at market showed Sclerotinia decay, it was found that the percentage of infection ranged from 5 per cent in some cars to as high as 75 per cent in others, the average for all the cars being 24 per cent.

The symptoms produced by these different fungi vary somewhat, but in certain stages of their development the fungi exhibit characteristics so similar that they can not easily be distinguished. A study of numerous shipments of snap beans from the South after arrival on the northern and eastern markets shows that the symptoms may vary from the partial decay of a few isolated pods to what is referred to by the trade as "nesting," a condition in which as many as a half peck of beans in the center of the pack, or elsewhere within it may be entirely decayed and more or less bound together in a mass of cottony mycelium. When nesting is observed, Sclerotinia or Rhizopus, especially the former, is suspected.

OCCURRENCE OF PYTHIUM APHANIDERMATUM

In the spring of 1925 a bad case of nesting was observed in a container of snap beans shipped from Florida. The beans were overrun with a cottony growth of mycelium, suggesting macroscopically Sclerotinia and isolated as such. A subsequent examination of the culture showed, however, that *Pythium aphanidermatum* (Edson) Fitzpatrick,[3] and not a species of Sclerotinia, had been isolated. Later shipments of beans were examined, and Pythium was frequently observed during the late spring and early summer.

Inasmuch as beans are seldom shipped from the South during the summer months, no more nesting caused by Pythium was found until fall, when it was again observed. Throughout the winter of 1925–26 little or no Pythium was noted. About the middle of April, 1926,

[1] Received for publication Nov. 9, 1926; issued April, 1927.

[2] RAMSEY, G. B. SCLEROTINIA SPECIES CAUSING DECAY OF VEGETABLES UNDER TRANSIT AND MARKET CONDITIONS. Jour. Agr. Research 31: 597–632, illus. 1925.

[3] Identified by Charles Drechsler.

with the coming of warmer weather, Pythium again occurred, the amount of loss increasing with the rise in temperature. These data seem to indicate that the rotting of beans caused by Pythium is to be expected only during the warmer months of the shipping season. This conclusion is tentatively warranted by the fact that the maximum and minimum temperatures for growth of the organism are high, the optimum being about 32° C.[4]

CHARACTER OF DISEASE CAUSED BY PYTHIUM APHANIDERMATUM

The symptoms produced by Pythium are not essentially different from those caused by some other fungi, as, for example, Sclerotinia. A microscopic examination of rotted beans shows that the cells are separated along the line of the middle lamellae. A liquid, probably mostly water, is released in the process of disintegration, thereby reducing the pods to a soft, pulpy mass.

A profuse growth of fine white mycelium, which develops in and about the cells and over the beans, binds the pods so tightly that they are torn into shreds if an attempt is made to separate them.

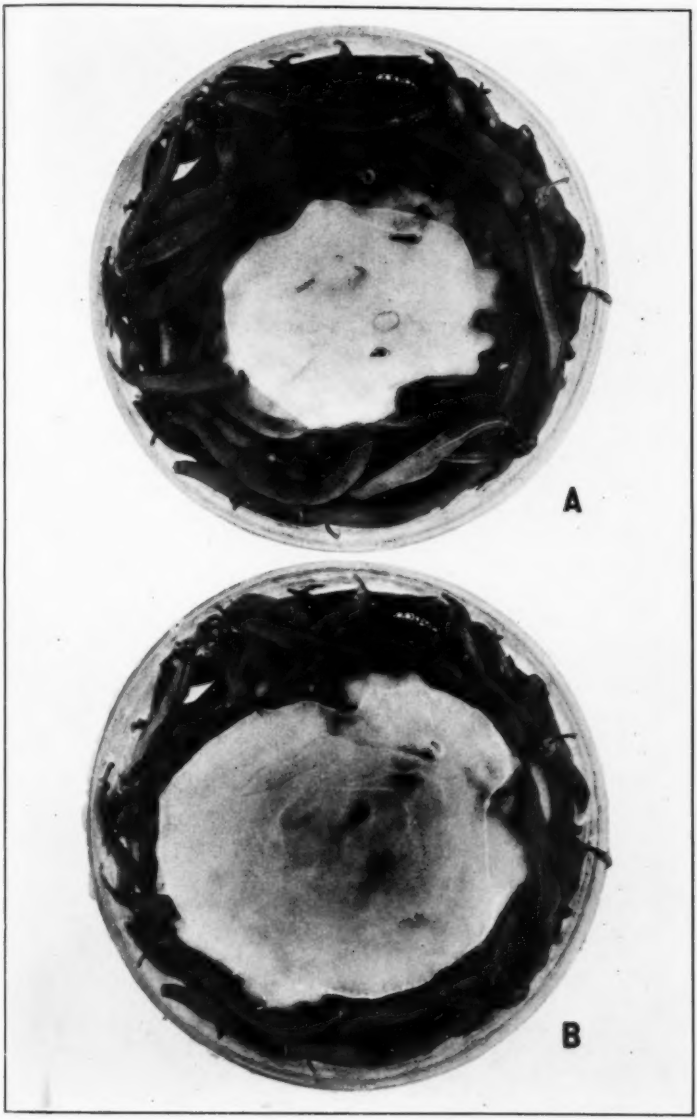
Pythium causes a very rapid destruction of beans in transit and under artificial conditions. Plate 1, A and B, shows the quantity of decay caused by Pythium in moist chambers at the end of four and five days, respectively, after inoculation.

Inasmuch as the beans are rendered very soft and watery, the term "cottony leak" can appropriately be employed to distinguish this disease from the watery soft rot caused by *Sclerotinia sclerotiorum*, with which it might be confused. Although there is a general similarity between the two diseases, the following gross symptoms will aid in distinguishing them. Sclerotinia frequently produces hard, nearly black sclerotia; Phythium, never. The mycelium of Sclerotinia is coarse, while that of Pythium is fine and more or less fluffy. Sclerotinia has a grayish colored mycelium, while that of Pythium is almost pure white.

INOCULATION EXPERIMENTS

As soon as snap beans were available in the fall of 1925, inoculation experiments were made with *Pythium aphanidermatum* for comparison with *Sclerotinia sclerotiorum*, *Rhizoctonia solani* Kühn, *Botrytis cinerea* Pers., and two species of Rhizopus—*R. tritici* Saito and *R. nigricans* Ehrb. In these experiments Pythium caused a more rapid decay than any of the other organisms. Beans of the same lot were thoroughly washed and held in moist chambers as controls. Some decay developed later and isolations from a number of pods gave, in almost every case, Pythium, showing not only that the organism was present but that it greatly predominated over other fungi. Several sets of inoculations were conducted with *P. aphanidermatum* in moist chambers at room temperature (about 25° C.). A wire support was placed in the moist chamber about 1.5 centimeters from the bottom and the portion above the support was filled with snap beans, which were then washed in running water. A little

[4] HARTER, L. L., and WHITNEY, W. A. MOTTLE-NECROSIS OF SWEET POTATOES. [To be published soon in Journal of Agricultural Research.]



A.—Beans in moist chamber four days after inoculation with *Pythium aphanidermatum*
B.—Same beans, 24 hours later

water was left in the bottom of the moist chamber in order to maintain a relatively high humidity. The inoculations were made at the center of the dish by inserting a quantity of mycelium into a wound made by breaking a pod into two parts. The mycelium spread from the point of inoculation in a radial direction to sound pods, eventually reducing them to a pulpy, watery mass. At the end of about five days most of the beans were partially or entirely decayed. (Pl. 1, B.)

Inasmuch as Pythiums are probably present in all types of soil, it was thought advisable to conduct a preliminary experiment to determine the pathogenicity of a number of strains[5] and species isolated from various hosts. Table 1 shows the strain (or species), the host from which it was originally isolated, the source of the culture, and the diameter of the nest formed in moist chambers at the end of five days.

On December 9, 1925, 1 bushel of snap beans of the Hodson wax variety was purchased on the open market in Washington, D. C., and apportioned among twenty 22-centimeter moist chambers. The beans were free of blemishes and were treated as described above. The first records were made two days after the inoculations and thereafter daily for three days.

TABLE 1.—*Species of Pythium, host from which it was isolated, source of culture, daily diameter of the decayed area, and average daily increase in diameter for the period of five days*

Species	Host from which isolated	Source of culture	Diameter of rot in centimeters				
			2 days	3 days	4 days	5 days	Average daily increase
Aphanidermatum	Bean	Original	S [a]	12.0	15.0	17.0	3.4
Do	do	do	S	8.0	11.0	15.0	3.0
Do	do	Reisolation	S	13.5	19.0	22.0	4.4
Artotrogus	Pea	Drechsler	O [b]	0.0	0.0	0.0	0.0
Complectens	Pelargonium	do	O	0.0	0.0	0.0	0.0
Debaryanum	Pea	do	M [c]	0.0	0.0	0.0	0.0
Do	do	do	S	2.5	4.0	4.5	0.9
Myriotylum	Cucumber	do	O	5.0	13.0	15.0	3.0
Splendens	Pelargonium	do	S	4.0	8.0	9.0	1.8
Ultimum	Bean	Original	M	7.0	11.5	13.0	2.6
Do	Cabbage	Drechsler	S	5.5	9.0	11.0	2.2
Do	Sweet potato	Original	O	3.0	7.5	9.0	1.8
5825	Pear	Drechsler	O	0.0	0.0	0.0	0.0
5826	Watermelon	do	O	0.0	0.0	0.0	0.0
5828	do	do	O	0.0	0.0	0.0	0.0
5831	Corn	do	O	0.0	0.0	0.0	0.0
5876	Watermelon	do	O	0.0	0.0	0.0	0.0
Controls (3)			O	0.0	0.0	0.0	0.0

[a] S = Decay is starting but not advanced enough to be measured.
[b] O = No indication of decay or mycelial growth.
[c] M = Mycelium starting to grow but no decay.

Table 1 shows that five species (*Pythium aphanidermatum*, *P. ultimum* Trow, *P. debaryanum* Hesse, *P. splendens* Braun, and *P. myriotylum* Drechsler, ined.)[6] are parasitic on beans. Of these five only two, *P. aphanidermatum* and *P. ultimum*, were isolated from beans. If the amount of decay produced in a given time (five

[5] "Strain" as here used refers to different isolations of the same organism and does not imply any morphological difference.
[6] This is a new species named by Drechsler, the description of which will be published later by him. It causes a pathological condition in cucumbers very similar to the "leak" caused by *P. aphanidermatum*.

days) is accepted as a criterion, *P. aphanidermatum* would seem to be the most aggressive parasite, followed in order by *P. myriotylum*, *P. ultimum*, *P. splendens*, and *P. debaryanum*. It is interesting to note in this connection that *P. debaryanum*, while able to cause decay when inoculated into a wound, was unable to attack sound tissue. On the other hand *P. aphanidermatum*, *P. ultimun*, *P. splendens*, and *P. myriotylum*, species penetrated seemingly unwounded cells with apparent ease.

Inoculations were made with three species of Pythium having spiny oogonia (*P. artotrogus* Mont., *P. 5828*, and *P. 5826*), none of which proved to be pathogenic. *P. 5828* has been briefly characterized by Drechsler [7] as having lobular zoosporangia grouped in "a mulberrylike aggregation consisting frequently of more than a score of subglobose communicating elements, from which the contents are delivered through an evacuation tube into a vesicle giving rise to more than a hundred zoospores. The other spiny form [*P. 5826*] associated with decay of watermelons exhibits sporangia that may be regarded as a modification of the subspherical type, consisting generally of a subspherical part together with an adjacent part of one or both hyphal elements between which it is intercalated, the evacuation tube arising from the venterlike part, or from the filamentous part, or very frequently from near the juncture of the two."

Pythium 5876, the third species from watermelon is, according to Drechsler, incompletely known and has not yet been determined. A Pythium identical with *P. 5825* has been isolated frequently from the roots of beans from Florida, but it seems incapable of causing any considerable decay of snap-bean pods. When inoculations were made according to the method described above, some softening of the pods adjacent to the center of inoculation took place, but the results plainly indicated that this species was incapable of causing any considerable damage. This species has never been isolated from decayed beans obtained from the markets, indicating that it is not likely to be of much consequence in transportation.

Little is known at present about the prevalence and distribution of the "leak" of beans. Inasmuch as this organism has been found associated with diseases of plants as widely separated generically as eggplant [8] (*Solanum melongena* var. *esculentum* Nees) and cucumber (*Cucumis sativus* Linn.), it is probably safe to predict that it may be found on beans from widely separated regions.

CONTROL MEASURES

From our present knowledge of the cottony leak of beans, certain recommendations for its control can safely be made. The evidence indicates that the disease originates in the field on beans resting on or partly covered by the soil. If such infected beans are shipped it is probable that some decay will result, the amount depending upon the promptness with which the beans are handled and conveyed to the market and the temperature and humidity to which they are subjected from the time they are gathered until they are marketed.

[7] DRECHSLER, C. THE COTTONY LEAK OF CUCUMBERS CAUSED BY PYTHIUM APHANIDERMATUM. Jour. Agr. Research 30: 1035–1042, illus. 1925.

[8] DRECHSLER, C. THE COTTONY LEAK OF EGGPLANT FRUIT CAUSED BY PYTHIUM APHANIDERMATUM. Phytopathology 16: 47–50, illus. 1926.

As decay is likely to occur in any container holding infected beans, it is advisable to grade the beans carefully and to discard any with blemishes or disease lesions before they are packed. The development of cottony leak is facilitated by high humidity and a fairly high temperature, and for this reason beans should be gathered, if possible, when the vines are dry, and kept in a cool dry place until they are shipped. To allow beans to remain in the hot sun for several hours or more before shipping provides the optimum conditions for the start of a decay which may cause considerable damage during transit. Beans are often wet when they arrive at the markets, showing that they have either been packed wet or that they have "sweat" during transit as a result of insufficient ventilation in the containers, improper ventilation of the car, or both.

In brief, for successful shipment it may be recommended: (1) That the beans be carefully graded and that any showing blemishes and diseased spots be thrown out; (2) that they be picked when the vines are dry; (3) that they be kept in a cool dry place while awaiting shipment; (4) that shipment be made in containers loose enough to permit the maximum amount of ventilation consistent with freedom from the danger of leakage and breakage; and (5) that precooling and refrigeration with adequate ventilation of the car be practiced where the crop is large enough to be shipped in carload lots. If care is taken to handle the crop under the best possible conditions from the time the beans are picked until they reach the consumer, little loss should result.

SUMMARY

A transit disease of beans (*Phaseolus vulgaris* Linn.) caused by *Pythium aphanidermatum* (Edson) Fitzpatrick has been investigated. This organism produces a "nesting" resembling that caused by Sclerotinia, and in general appearance is indistinguishable from the latter except in a few minor details. *P. aphanidermatum* causes a more rapid destruction of beans than Sclerotinia and has a more abundant growth of almost pure white cottony mycelium.

Inoculation experiments were made with a number of other species of Pythium some of which, although not isolated from shipped beans, proved to be parasitic. *Pythium ultimum*, *P. splendens*, and *P. myriotylum* ined. named species were able to produce nesting similar to that caused by *P. aphanidermatum*. One isolation of *P. debaryanum* caused some decay when inoculated into a wound but was unable to attack sound tissue.

None of the Pythiums with spiny oogonia which were tried were found to be parasitic.

Pythium aphanidermatum is very common on beans in transit during the warmer months of the shipping season.

A TECHNIC FOR USE WITH HOMOPTEROUS VECTORS OF PLANT DISEASE, WITH SPECIAL REFERENCE TO THE SUGAR-BEET LEAF HOPPER, EUTETTIX TENELLUS (BAKER)[1]

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INTRODUCTION

So far as the writer is aware, no apparatus has yet been reported by means of which the virus causing curly-top of sugar beet can be separated from both the insect vector and the host plant. In the course of studies of *Eutettix tenellus* (Baker) and its relation to curly-top, such an instrument was devised.

METHODS AND APPARATUS

At the beginning of these studies it was found necessary to evolve some method by which the insect could be fed artificially. Pads of thick filter paper soaked with food solution were first used, the insects being kept on them in Petri dishes. This method failed because the pads soon developed molds and could not be kept even moderately sterile. The activity of the insect also made difficult the frequent transfers that were necessary where the Petri-dish method was used. The next trials were with membranes made of collodion on a cheesecloth base, these being sealed over the ends of test tubes containing the food solutions. In a few cases *E. tenellus* was induced to feed through these membranes for periods of several days. As a rule, however, collodion membranes become very hard and this method also was abandoned. Gelatin membranes were found to be too temporary in character and they provided a fertile substratum for fungous growth.

Through a local drug store an animal mesentery was obtained which is sold under the name of "fish-skin." It has been tested quite thoroughly and has thus far proved to be the most practical of any of the materials tried. No. 4 rubber stoppers are drilled out with as large a drill as can be used and a small circle of the membrane fastened over the hole in the large end of the stopper, either with shellac or with a glue made of automobile celluloid dissolved in acetone. Any waterproof adhesive will no doubt suffice. This stopper is then fitted into a short tube containing the food solution. A larger stopper holds the tube in place in a glass cylinder which serves as a cage for the insects. This arrangement is illustrated in Figure 1, A.

For the feeding of a large colony, or where mass action is desired, a small sack may be made of the membrane, which is then filled and hung free in a cage. (Fig. 1, B.) This modification is only of service where the concentration of the food material need not be

[1] Received for publication Aug. 8, 1926; issued April, 1927.

kept constant. With the smaller set-up (A) the evaporation surface is very small and little loss is experienced; furthermore, this equipment has the advantage of making more delicate tests possible.

It has been found that the mortality with this technic is very high, but whether this is due to the inability of the insect to find

FIG. 1.—Apparatus for feeding *Eutettix tenellus:* A, set-up first used; B, modification of A, employed for feeding insects in large numbers (experience has shown this to be most practical)

the food or to the toxic nature of the food itself is difficult to determine. That *Eutettix tenellus* feeds through these membranes there is no doubt since the feeding has been repeatedly observed, and on one occasion the membrane was peppered with tiny oozings from the feeding punctures.

ISOLATION OF CURLY-TOP ORGANISM FROM INSECT AND HOST PLANT

A wide range of interesting possibilities is thus opened up, particularly, in this case, with regard to studies on the properties of the virus which the insect carries. For some time the writer did not find it possible by this method to produce the disease from the juice of a diseased beet or from the sap of the wild host plants, but after many attempts the disease has been successfully transmitted from juice expressed from diseased beets to noninfective leaf hoppers and thence to healthy beets by means of this technic. The positive result obtained by the writer was paralleled by similar results obtained by H. H. Severin, of the California Agricultural Experiment Station.

Extracted juice rapidly loses its original character and becomes toxic to the insect, so that it is not safe to feed *Eutettix tenellus* on such juice for more than two or three days at 70° F. Tap water or weak sugar solutions have been the substances on which the writer has been able to sustain the life of the insect for the longest periods. *E. tenellus* fed for two weeks on a dilute cane-sugar solution and one specimen of *Geocoris bullatus* Say was kept alive for a month on tap water.

Nutrition studies with sucking insects should be much simplified by this apparatus, since the quality of the food can be rather exactly controlled. Temperature studies are also facilitated, since the set-up can be used in connection with apparatus for maintaining controlled temperatures—a very difficult matter if it is necessary to feed the insect directly on the plant.

NEW SPECIES AND NEW FORMS OF ICHNEUMONIDAE PARASITIC UPON THE GIPSY-MOTH PARASITE, APANTELES MELANOSCELUS (RATZEBURG)[1]

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INTRODUCTION

One of the most important of the parasites of the gipsy moth introduced into the United States for the control of that insect is *Apanteles melanoscelus* (Ratzeburg). In this country its effectiveness is more or less reduced by the attack of certain native hyperparasites. Six of these hyperparasites are discussed in this paper, four being described as new species.

Hemiteles apantelis, new species

Female.—Length 4 mm. Head minutely granulate, slightly broader than thorax; temples narrower than eyes, rather strongly convex; combined face and clypeus nearly twice as broad as long, with a median elevation extending from below antennae to apex, the clypeus not separated, broadly rounded at apex with narrow reflexed margin; malar space slightly longer than basal width of mandible; cheeks convex; mandibles neither swollen at base nor constricted in middle; antennae as long as head, thorax, and first tergite, first three flagellar joints slender, first and second equal, third slightly shorter, flagellum apically barely thicker than at base. Thorax granulate with only the posterior face of propodeum polished; notauli subobsolete; sternauli fine, extending somewhat more than half the length of pleurum; scutellum strongly convex, not margined; propodeum completely areolated, basal lateral areas large, areola hexagonal with base and sides beyond costulae much shorter than the other sides; stigma nearly three times as long as broad, radius at about the middle, apical abscissa of radius evenly curved, the radial cell shorter on metacarpus than stigma; areolet open, stub of cubitus beyond recurrent parallel with radius; base of second discoidal cell longer than apex of brachial cell; nervulus postfurcal; nervellus inclivous, broken below middle. Abdomen as long as head and thorax, granulate basally, subpolished apically; first tergite flattened, without dorsal carinae, spiracles shortly beyond middle, postpetiole twice as broad as petiole; abdomen subcompressed at apex; ovipositor sheath about twice as long as first segment, slender.

Black, with basal half of antennae, mandibles, and legs beyond coxae dark reddish; wings hyaline with dark veins and stigma and two dusky bands, one below stigma and the other (sometimes wanting) along basal vein, stigma pale at base, tegulae brown.

Male.—Except sexually, essentially like female, but the propodeal carinae are somewhat weaker. the areola nearly equilateral; wings hyaline; legs piceous, with apical joint of front and middle trochanters, their femora at base and apex, their tibiae in front, and extreme base of hind femur and tibia, whitish; antennae black with only scape and pedicel pale beneath; tegulae pale.

Type locality.—Rye, New Hampshire.

Host.—*Apanteles melanoscelus* (Ratzeburg).

Type.—Cat. No. 28058, U.S.N.M.

Described from three females and three males, the two paratype females from Saugus and Boylston, Massachusetts, the males each the progeny of one of the females. The allotype is the progeny of the type.

[1] Received for publication Oct. 29, 1926; issued April, 1927.

Gelis apantelis, new species

This species is dimorphic, the male being winged.

In Strickland's key [2] the female runs to *longistylus* (Strickland), but in that species the antennae are nearly as long as the body, very slender filiform, with the first joint of flagellum more than four times as long as thick at apex; the propodeum comprises fully half the total length of the thorax and is barely arched above the level of the mesoscutum; the legs are exceptionally slender; the ovipositor sheath distinctly more than one and one-half times the length of the first segment; and the abdominal color quite different. The male runs nowhere conclusively.

In Brues's key [3] both sexes run to *ottawäensis* (Harrington), but in that species the mesoscutum is very short, the suture separating it from the pronotum is subobsolete, and the species belongs to the subgenus Micromeson Strickland. Because of the unusually slender first tergite the true *ottawäensis* runs in Brues's key to *texanus* (Cresson).

Female.—Length 2 to 4 mm. Head twice as broad as thorax and slightly more than twice as broad as thick medially; temples convexly sloping (in the smallest specimen the head is relatively thicker with broader, more strongly convex temples); face nearly twice as broad as long; malar space slightly longer than basal width of mandibles; eye two-thirds as broad as long; diameter of lateral ocellus from one-half to two-thirds the length of ocell-ocular line, which is normally only half as long as postocellar line, but in small specimens relatively longer; mandibles slightly swollen near the base; antennae about two-thirds as long as body, slightly thicker toward apex, flagellum 16 to 19 jointed, first and second joints subequal and about three times as long as thick, others successively shorter, subapical ones fully as broad as thick. Thorax slightly more than twice as long as broad; mesoscutum barely as long as broad, about a half longer than pronotum medially, rather broadly rounded anteriorly; scutellum rather large but very faintly separated, not much shortened; propodeum comprising distinctly less than half the dorsal length of thorax, strongly arched above level of mesoscutum and frequently medially impressed at top, apical carina obsolete to distinct and highly arched medially, pleural carina weak to obsolete; legs rather stout, hind femur hardly five times as long as deep. Abdomen twice as broad as thorax, distinctly longer than head and thorax, with sparse pubescence; first tergite rather slender, barely half as wide apically as long, the sides nearly straight; second tergite barely longer than third, gastrocoeli obsolete; ovipositor slender, sheath a half longer than first tergite.

Head, thorax, first two tergites, and legs ferruginous to fusco-ferruginous; rest of abdomen black; antennae testaceous, black at apex.

Male.—Head barely wider than thorax; eyes large; malar space distinctly shorter than basal width of mandible; temples narrow; diameter of lateral ocellus from twice to several times as long as ocell-ocular line; antennae slender filiform, tapering apically, nearly as long as body, first flagellar joint distinctly longer than second. Thorax normal with very large scutellum, granulate; propodeum subcompletely areolated, the longitudinal carinae between the transverse carinae subobsolete; basal area large, quadrangular, areola hexagonal, costulae far before middle; petiolar area not or but little larger than areola and of nearly the same shape; basal areas granulate, others shining rugulose; legs very slender; wings fully developed; stigma hardly three times as long as broad, radius beyond middle. Abdomen narrow, first tergite less than twice as wide at apex as petiole; tergites 1 and 2 longitudinally striate, third obscurely granulate, others subpolished.

Head and thorax black; abdomen black, with third tergite, apices of first and second, sides of second, and frequently basal middle of fourth, yellow; scape and mandibles yellowish; palpi pale; legs testaceous, trochanters pale, hind tibia and all tarsi fuscous; wings hyaline, venation dark, stigma pale at base.

Type locality.—Melrose Highlands, Massachusetts.

Host.—*Apanteles melanoscelus* (Ratzeburg).

Type.—Cat. No. 28059, U.S.N.M.

Described from a series of 8 females and 13 males, all of the males the progeny of 4 of the females, reared at the Gipsy Moth Parasite Laboratory.

The allotype is the progeny of the type.

[2] STRICKLAND, E. H. THE PEZOMACHINI OF NORTH AMERICA. Ann. Ent. Soc. Amer. 5: 115. 1912.

[3] BRUES, C. T. DESCRIPTIONS OF NEW ANT-LIKE AND MYRMECOPHILOUS HYMENOPTERA. Amer. Ent. Soc. Trans. 29: 120, 121. 1903.

Gelis inutilis, new species.

This species is also dimorphic with winged males.

Very similar to *apantelis* Cushman, but differing constantly in the available material as follows:

Female.—Length 3.5 mm. Ocell-ocular line nearly as long as postocellar line (in specimens of the same size in *apantelis* it is only about half as long as ocell-ocular line); scutellum very short and broad, weakly separated; propodeum not arched above level of mesoscutum, not medially impressed at top; hind tibia nearly as thick near apex as femur; first tergite fully twice as long as wide apically; ovipositor sheath hardly a half longer than first tergite.

Color as in *apantelis*.

Male.—Differs from male of *apantelis* as follows: Eyes not especially large; malar space as long as basal width of mandible; diameter of lateral ocellus not or barely as long as ocell-ocular line; hind tibiae rather conspicuously stout.

Type locality.—Eastern Massachusetts.

Host.—*Apanteles melanoscelus* (Ratzeburg).

Type.—Cat. No. 28060, U.S.N.M.

Described from two females and five males, the males progeny of the females, all reared from the host at the Gipsy Moth Parasite Laboratory.

The allotype is the progeny of the type.

Gelis nocuus, new species.

Another dimorphic species with winged males.

The female runs in Strickland's key [4] to *similis* (Strickland), but is at once distinguishable by its much shorter and more slender legs and antennae and less distinct scutellum. In Brues's key [5] it runs to *micariae* (Howard), in which the antennae are even stouter and shorter, being barely longer than head and thorax, and the clypeus is so short that the labrum is partially exposed.

The male runs in Strickland's key to *flavocinctus* (Ashmead), but differs in its entirely black head and thorax and in the color pattern of the abdomen. In Brues's key it runs to *micariae* (Howard), to which it is extremely similar, but from which it can be distinguished by the fact that the clypeus is hardly twice as broad as long and is obliquely impressed on each side at the apex so that it appears subacute, while in *micariae* it is more than twice as broad as long and apically broadly rounded.

Female.—Length 3.5 mm. Head barely twice as broad as thorax and only slightly more than twice as broad as thick medially; temples convexly receding; eyes very slightly divergent below; face hardly twice as broad as long; malar space slightly longer than basal width of mandible, furrow distinct; mandible slightly swollen basally; antennae somewhat longer than head and thorax, rather stout especially beyond middle, flagellum 18-jointed, basal joint hardly three times as long as thick at apex, subequal to second. Thorax hardly twice as long as thick; mesoscutum with prominent tubercles laterally, scutellum large and very faintly indicated; postscutellum obsolete; propodeum with only the lateral portions of apical carina, sloping strongly from basal third and arched only slightly above level of mesoscutum; prepectal carina convergent above with anterior margin of pleurum; legs stout. Abdomen longer than head and thorax by nearly the length of first tergite; first tergite fully twice as long as broad at apex, much longer than second; second and third equal; ovipositor sheath slightly longer than first tergite.

Head and thorax dark ferruginous; antennae paler at base, fuscous at apex; legs testaceous, hind femur and tibia apically more or less infuscate; first two tergites ferruginous; second more or less piceous; others black; extreme apex brownish.

Male.—Head with temples convexly sloping; diameter of lateral ocellus from as long as to distinctly longer than ocell-ocular line; malar space hardly longer than basal width of mandible; antennae nearly as long as body, slender filiform. Thorax granulate, pronotum laterally and propodeum behind more or less rugulose; notauli obsolete; propodeum with apical carina strong throughout, basal carinae medially and pleural carinae distinct, the carinae more or less obsolete, areolet more or less distinctly defined, rather large hexagonal, petiolar

[4] STRICKLAND, E. H. THE PEZOMACHINI OF NORTH AMERICA. Ann. Ent. Soc. Amer. 5: 116. 1912.

[5] BRUES, C. T. DESCRIPTIONS OF NEW ANT-LIKE AND MYRMECOPHILOUS HYMENOPTERA. Amer. Ent. Soc. Trans. 29: 120. 1903.

area much longer than posterior lateral areas; wings large, stigma nearly half as broad as long, with radius beyond middle; legs slender. Abdomen granulate striate basally, subpolished apically, narrow, postpetiole much longer than broad.

Head and thorax black; mandibles, scape, lower angle of pronotum, and legs red, hind tibiae and tarsi slightly infuscate, flagellum black; wings hyaline, venation dark, stigma pale at base and apex; abdomen flavo-ferruginous, blackish at apex.

Type locality.—Shrewsbury, Massachusetts.

Host.—*Apanteles melanoscelus* (Ratzeburg).

Type.—Cat. No. 28061, U.S.N.M.

Described from 6 females and 9 males all reared from the host at the Gipsy Moth Parasite Laboratory, 3 of the males, including the allotype, the progeny of the type.

Gelis bucculatricis (Ashmead)

Pezolochus bucculatricis Ashmead, 1890, U. S. Nat. Mus. Proc. 12: 420, ♀ ♂; Dalla Torre, 1901–02, Cat. Hym., p. 615.

Theroscopus americanus Ashmead, 1896, Amer. Ent. Soc. Trans. 23: 211, ♂.

Hemiteles ashmeadii Dalla Torre, 1901–02, Cat. Hym., p. 643 (not *americanus* Cresson).

Pezolochus bucculatricis Strickland, 1912, Ann. Ent. Soc. Amer. 5: 139.

Pezomachus americanus Strickland, op. cit.

Only two of the three specimens of the type series of *bucculatricis*, a female and a male, are left. The female is hereby designated the holotype and the male the allotype.

The unique type of *americanus* is practically identical, except in its larger size, with the allotype of *bucculatricis*. Most of the 27 specimens from *Apanteles melanoscelus* are even larger, and include the hitherto undescribed winged male.

The genotype of Pezolochus Foerster is unknown to the writer. That genus is said to differ from Gelis by its short face. The face in *bucculatricis*, while perhaps somewhat shorter than in some other species of Gelis, is not conspicuously so, and the species is certainly a true Gelis.

Much more characteristic of this species is the carination of the propodeum, which is nearly identical in all three forms. The apical carina is strong and describes nearly an even semicircle between the obsolete pleural carinae; all the other carinae are absent. In the winged male both the apical and pleural carinae are somewhat stronger than in the other two forms.

The unsatisfactory original description of the species makes redescription advisable.

Female.—Length 2 to 4 mm. Head nearly twice as broad as thorax; temples convexly receding; eyes fully four-fifths as broad as long, divergent below; diameter of lateral ocellus hardly half as long as ocell-ocular line; face nearly twice as broad as long; malar space nearly as long as basal width of mandibles, with a distinct malar furrow (in larger specimens the head is relatively shorter from front to back, with correspondingly less strongly convex temples, longer postocellar line, and shorter ocell-occipital line (in the series considered in this study all the gradations in these characters are not present, but this is undoubtedly due to the fact that not all the gradations in size are available); mandibles subangularly swollen near base; antennae about three-fourths as long as body, slender, slightly thickened toward apex, flagellum 17 to 20 jointed, first joint about four times as long as thick, second very nearly as long as first, those beyond gradually shorter, those of apical fourth subequal and of equal length and thickness. Thorax more than twice as long as broad; mesoscutum slightly longer than broad, acutely rounded anteriorly, about twice as long medially as pronotum, slightly impressed in posterior middle; scutellum small but distinct; prepectal suture complete, convergent with anterior margin of mesopleurum; propodeum in profile evenly arched from base to carina, thence flat, higher than mesoscutum; legs rather slender, hind femur about five times as long as deep. Abdomen as long as head and thorax, about half as broad as long and twice as broad as thorax, with very short, sparse pubescence; first tergite nearly or quite two-thirds as broad at apex as long, gradually broadening from base to apex, petiole not or only faintly constricted, least so in smallest specimens; second tergite slightly longer than third, gastrocoeli distinct; ovipositor sheath barely as long as first tergite.

Head and thorax pale ferruginous to fuscous with vertex and sutures slightly darker; mandibles pale; antennae pale testaceous basally, more or less infuscate apically; legs testaceous to fuscous, the coxae, at least below, trochanters, tibiae above and basally, and tarsi always of the lighter color; basal two tergites ferruginous, sometimes slightly infuscated with the apices yellowish, other tergites black, with apices indistinctly reddish, as are sometimes also the apical tergites.

Wingless male.—Of same length as female but more slender, with head distinctly less than twice as broad as thorax; larger scutellum; distinct postscutellum, tegulae, and wing vestiges; longer, more slender, filiform flagellum with first joint much longer than second; eyes larger and less strongly diverging below; diameter of lateral ocellus half to two-thirds as long as ocell-ocular line; propodeum not arched above level of mesoscutum, with medially stronger apical carina and more shining petiolar area; narrower parallel-sided postpetiole; and more slender legs.

Color arranged as in female but generally darker; on abdomen the ferruginous color is frequently replaced by fuscous or black, the apices of the first two tergites rather pale yellow.

Winged male.—Compared with wingless male, differs as follows: Head barely broader than thorax, diameter of lateral ocellus from two-thirds to fully as long as postocellar line; thorax of normal form, with fully developed mesothorax and wings; and propodeum relatively smaller. Wings hyaline with a faint cloud below the stigma and slightly infumate along the basal vein; stigma more than half as broad as long, fuscous with base whitish, radius beyond middle; radial cell shorter on metacarpus than stigma; discocubitus angularly broken at or near middle, ramellus frequently present; second recurrent arcuately inclivous; nervulus postfurcal; nervellus slightly inclivous and broken below middle.

Color same as in wingless male.

Redescribed from type and allotype of *bucculatricis;* type of *americanus;* one female and one wingless male from Ohio; one female reared from an Apanteles cocoon in Riley County, Kansas, by J. B. Norton; and 8 females, 12 wingless males, and 7 winged males all reared at the Gipsy Moth Parasite Laboratory from cocoons of *Apanteles melanoscelus.* Many of the latter lot are progeny of certain of the females.

Gelis urbanus (Brues)

Pezomachus urbanus Brues, 1910, Wis. Nat. Hist. Soc. Bul. 8: 70, ♂.

The writer believes he is correct in referring to this species a series of 21 specimens including, in addition to the wingless male, both the female and the winged male. The last two forms were unknown to the author of the species. They are described below. A brief comparative description of the wingless male is also included.

Female.—Length 3 to 4 mm. Head twice as broad as thorax, about twice as broad as long medially from above; temples convexly receding; face nearly twice as broad as long; malar space fully as long as basal width of mandible, furrow distinct, eye three-fourths as broad as long; diameter of lateral ocellus from distinctly less than to about half as long as ocell-ocular line; width of ocellar triangle distinctly less than length of ocell-occipital line; (variation in the head is of the same nature as that in *bucculatricis*); mandibles not basally swollen; antennae three-fifths as long as body, rather stout, slightly thicker toward apex, flagellum 18-jointed; basal joint hardly four times as long as thick, slightly longer than second, those beyond successively shorter, subapical ones quadrate. Thorax with mesoscutum about as long as broad, acutely rounded anteriorly, less than twice as long as pronotum medially; scutellum faintly defined anteriorly; prepectal carina complete, convergent with anterior margin of mesopleurum; propodeum with apical carina complete, highly arched medially, the propodeum in profile evenly arched from base to carina, slightly higher than mesoscutum, pleural carinae wanting; legs rather stout, hind femur less than five times as long as deep. Abdomen longer than head and thorax by about the length of the first segment, half as broad as long and twice as broad as thorax, pubescence very sparse and short; first tergite nearly twice as long as broad at apex, sides nearly straight; second tergite slightly longer than third, gastrocoeli obsolete; ovipositor sheath subequal in length to first tergite.

Head fusco-ferruginous, black above; antennae ferruginous, black at tips; thorax from pale ferruginous to fusco-ferruginous with sutures darker; legs testaceous to fuscous, paler basally and on upper surface of hind tibia; basal two

tergites ferruginous, sometimes yellowish apically; second more or less infuscate basally, others black, in lighter specimens with apex of second tergite and the apical tergites somewhat reddish.

Wingless male.—This is the form described by Brues. Of same length as female but more slender, with distinct scutellum, postscutellum, tegulae, and vestiges of wings, larger mesoscutum and ocelli, shorter malar space, narrower face, lower propodeum, filiform antennae with basal joint of flagellum distinctly longer than second, more slender legs and abdomen. In color of head and thorax like female but averaging darker, with propodeum distinctly darker than mesothorax; abdomen black with apices of first two tergites yellowish and of third sometimes reddish.

Winged male.—Head barely broader than thorax; diameter of lateral ocellus from two-thirds to fully as long as ocell-ocular line; thorax and wings fully developed; propodeum nearly straight above, with only the petiolar and apical pleural areas defined, pleural carinae obsolete; wings hyaline immaculate, veins and stigma black, latter pale at base, stigma nearly three times as long as broad, radius at apical third, radial cell shorter on metacarpus than stigma, discocubitus subangular before middle; second recurrent arcuately inclivous, nervulus slightly spostfurcal, nervellus inclivous and broken below middle.

Black, the face and pronotum sometimes stained with reddish and the basa two tergites yellow at apex; antennae and legs as in wingless male.

Redescribed from a series of 7 females, 11 wingless males, and 3 winged males, all reared from cocoons of *Apanteles melanoscelus* at the Gipsy Moth Parasite Laboratory. All the males and one of the females are progeny of the other six females.

DISPERSION OF THE ANGOUMOIS GRAIN MOTH TO WHEAT FIELDS[1]

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INTRODUCTION

In contrast to the behavior of the majority of insect enemies of stored wheat, the Angoumois grain moth (*Sitotroga cerealella* Oliv.) begins its attack upon the crop before it is harvested. Were this not the case the control of the species would be simplified and the moth would be rendered incapable of developing the severe infestations which appear over large areas of the wheat region of the eastern part of the United States, where in some years it is a very destructive pest in harvested wheat. Since the elimination of preharvest infestations would reduce the insect to comparative impotency, it is desirable to examine the character of these infestations and to investigate the factors which make them possible.

The principal questions that arise in a study of preharvest infestation are these: What are the sources from which the parent moths fly to wheat fields? How is infestation in the field distributed with respect to these sources? What is the degree of infestation of wheat in the field? Do the insects pass the winter within kernels that are planted in the fall, and are they able subsequently to infest growing wheat? At what stage in the development of the wheat plant in the spring can the species become established in it? This report presents information in answer to the first three of these questions; the answers to the last two have not yet been satisfactorily determined.

Data obtained in 1924, 1925, and 1926 are here summarized and discussed. These are based on inspections of the conditions on different farms and on the infestations found in samples of wheat heads collected at harvest time in the field. Since it is impossible to take samples through the center of a wheat field before the grain is cut without trampling a considerable quantity of it, samples were taken from shocks, and visits to farms were begun as soon as harvesting operations started. Farms were inspected upon which shocked wheat was present within a few hundred feet of the farm buildings. Each sample consisted of three 6-pound paper bags of wheat heads, the bags being filled about three-quarters full. On each farm a sample, designated as No. 1, was taken from two or three shocks which were located nearest to the farm buildings or to other probable sources of moths. In most cases a second sample was taken at a greater distance from the moth sources; and a third sample was taken from shocks still farther away, usually in line with the shocks from

[1] Received for publication Oct. 23, 1926; issued April, 1927.

which samples No. 1 and No. 2 had been obtained. In choosing the area to be sampled, the desirability of avoiding the parts of a field in the vicinity of possible moth sources on neighboring farms was recognized.

Before the wheat was sampled in the field the owner's experiences with the moth were noted so far as possible, and, with a few exceptions, any grain in storage on the place was examined for infestation. A rough map was made of each farm, showing its location, the location of different kinds of stored grain, and the approximate direction and estimated distance of the sampled shocks from possible sources of moths. The apparent condition of the stored grain with respect to moth infestation and moth parasites was also recorded. Any litter remaining on the sites of mows where wheat had been piled before threshing was examined, and in 1925 and 1926 the presence of loose and baled wheat straw was noted.

In 1924 the inspections were made in west-central Maryland, mainly in Montgomery County. Much of the same area was gone over in 1925, and samples were also taken in southern Maryland (St. Mary's County), in the Shenandoah Valley in Virginia, in southeastern Pennsylvania, and on one farm in Delaware. In 1926 farms were inspected and samples were taken on the Eastern Shore of Maryland, in central and northern Maryland, and in southeastern Pennsylvania. The material collected was kept for observation in an outdoor insectary.

SOURCES FROM WHICH THE MOTHS FLY TO WHEAT FIELDS

It has been known for many years that the moths fly from stored grain, in which they pass the winter in immature stages, and lay eggs upon the maturing wheat in the fields. Duhamel du Monceau and Tillet [2] in 1760 and 1761 made convincing observations on the flight of moths to fields of wheat. According to their records, made during a period of very great abundance of the insect, the moths left the infested granaries in large numbers at dusk, and during the early evening they could be seen on the wheat heads in the fields, mating and depositing their eggs. Similar observations have been published since, notably by King,[3] who studied the insect in 1917 in the vicinity of York, Pa. In the spring of that year he found very little wheat on farms. Infested kernels were observed in small quantities on most farms in such situations as floor cracks, in the litter where wheat mows had been, and in some cases in wheat screenings. No positive evidence was found to show that the insect overwintered in ear corn stored in cribs.

During their harvest-time inspections in 1924 the writers made a special effort to locate farms on which wheat was stored in considerable quantities, but only a few such farms were found. From the observations made, it appeared that corn was by far the most important source of moths in 1924. As shown in Table 1, it was either a known or a suspected source on every farm inspected, with wheat in bins as an additional source in three cases, wheat litter on mow

[2] DUHAMEL DU MONCEAU, [H. L.], and TILLET [M.]. HISTOIRE D'UN INSECTE QUI DEVORE LES GRAINS DE L'ANGOUMOIS; AVEC LES MOYENS QUE L'ON PEUT EMPLOYER POUR LE DETRUIRE. 314 p., illus. Paris 1762.

[3] KING, J. L. THE ANGOUMOIS GRAIN MOTH. Penn. Dept. Agr., Bur. Plant Indus. Circ. 1, 14 p., illus. 1920.

TABLE 1.—*Dispersion of the Angoumois grain moth to wheat fields, 1924*

Farm No.	Date of farm inspection and sampling	Sample No.	Probable sources of moths	Estimated distance of sampled shocks from probable sources of moths	Number of emerged moths	Estimated number of kernels in sample	Estimated infestation
				Feet			*Per cent*
1	July 10	1	Corn	250	27	7,800	0.35
		2	do	600	24	10,100	.24
2	do	1	Corn, wheat	300	73	21,100	.35
		2	do	600	10	18,600	.05
		3	do	900	5	18,700	.03
3	July 11	1	Corn	50	23	9,300	.25
		2	do	250	1	13,900	.01
4	do	1	do	250	15	13,400	.11
5	do	1	do	400	22	14,000	.16
6	do	1	do	400	18	8,800	.20
		2	do	650	16	9,000	.18
7	do	1	do	50	20	12,000	.17
		2	do	200	9	12,300	.07
		3	do	600	0	9,800	.00
8	July 12	1	do	100	21	11,500	.18
		2	do	400	6	13,500	.04
		3	do	800	3	10,300	.03
9	do	1	do	300	7	9,400	.07
10	do	1	do	300	22	9,300	.24
11	do	1	do	250	11	10,000	.11
		2	do	500	0	10,700	.00
12	July 14	1	do	200	46	11,300	.41
		2	do	400	6	12,600	.05
		3	do	600	5	6,400	.08
13	do	1	Corn, wheat	600	12	12,400	.10
		2	do	700	11	13,100	.08
		3	do	1,000	6	12,500	.05
14	do	1	Corn	30	88	8,200	1.07
		2	do	180	16	11,400	.14
15	do	1	do	150	17	9,200	.18
		2	do	300	0	10,000	.00
16	do	1	do	50	70	10,500	.67
		2	do	250	48	12,400	.39
17	do	1	do	50	95	10,400	.91
18	do	1	do	20	18	11,200	.16
		2	do	120	4	10,500	.04
19	July 15	1	do	30	92	8,100	1.14
		2	do	180	15	9,800	.15
20	do	1	Corn; wheat in litter	20	79	6,800	1.16
		2	do	170	28	10,600	.26
21	do	1	Corn	100	10	10,900	.09
		2	do	250	2	14,900	.01
22	do	1	do	300	20	14,800	.14
		2	do	500	3	15,900	.02
23	July 16	1	do	100	180	10,900	1.65
		2	do	300	14	14,600	.10
24	do	[a]1	do	50	0	7,500	.00
25	do	1	do	200	2	14,300	.01
26	do	1	do	100	224	10,900	2.06
		2	do	300	58	14,600	.40
27	July 17	1	Corn, barley	300	21	10,700	.20
28	do	1	Corn; wheat in litter	40	24	8,900	.27
		2	do	250	11	8,700	.13
29	do	1	Corn	75	37	14,000	.26
30	do	1	Corn, barley	250	81	14,400	.56
		2	do	450	21	13,400	.16
31	do	1	Corn	50	82	6,300	1.30
32	July 18	1	do	250	20	12,700	.16
33	do	1	do	200	55	15,400	.36
34	July 19	1	do	75	7	11,600	.06
		2	do	375	0	12,700	.00
35	do	1	Corn, wheat	150	15	9,400	.16
			Total		1,876	718,400	
			Average	288	30	11,587	.26

[a] Bearded wheat; all other samples beardless.

sites in two cases, and barley in two cases. Unrecorded wheat straw was probably an auxiliary source on some farms. In 1925 the rôle of corn as a moth reservoir was less marked.

It is probable that the unusual abundance of the moth in the wheat crop of 1923 caused a considerable infestation of the corn in the field. The corn crop was good and the carry-over to 1924 was extensive. Field infestation of corn in the fall has been observed by the writers in Maryland; and it probably occurs, to an extent depending on weather conditions and moth abundance in the wheat crop, throughout the eastern soft red winter wheat area, including southeastern Pennsylvania, Delaware, Maryland, Virginia, western North Carolina, and northeastern Tennessee.

Moths were found in stored grain or litter on 27 of the 35 farms visited in 1924. They were observed to fly from ear corn, when the heaps of ears were disturbed, on 26 of the farms. The corn infestations were light except in the case of farm 30, where the moths were very numerous.

Farms 3, 4, 5, 19, and 26 had wheat in storage, but apparently it was uninfested. On farms 3, 4, and 19 only a bushel or two of wheat was on hand. Some of the farmers had fumigated their wheat with carbon disulphide, although the dosages and methods used were usually not such as would be expected to produce the best results.

Farm 6 had oats in storage, but apparently they were not infested. Although no moths were seen in the corn on farms 4, 9, 10, 24, 25, 27, 28, 29, and 33, the infested condition of the samples taken in fields adjacent to the corn (except on farm 24) indicated that moths had emerged from the corn at some time during the ripening of the wheat. This is to be expected, since a number of records are to be found which show that moth emergence from grain is characterized by surges; the insects emerge in large numbers for a few days and emergence then falls off until another period of abundance begins. King [4] noticed that emergence near York, Pa., in 1917, was greatest between June 5 and 15 and that moths were seldom seen after June 20.

Wheat on several of the farms visited in 1924 had evidently produced moths shortly before the writers' inspection. The owner of 900 bushels of wheat on farm 13, where large numbers of parasites but no moths were found, stated that moths had recently been numerous. The condition of several hundred bushels of wheat on farm 2 indicated that emergence had been plentiful, but at the time of inspection no moths were present. The grain swarmed with hymenopterous parasites, however, and a predacious mite, doubtless *Pediculoides ventricosus* Newport.

On farms 20 and 28 litter, consisting of broken straw, chaff, and scattered kernels of wheat, located in barns or barracks where wheat had been piled in mows for curing, was found infested. A moth was seen on shocked wheat in the field on farms 2, 21, and 22 at a distance of 200, 250, and 300 feet from stored corn which harbored moths.

In 1925 the harvesting of wheat began two or three days earlier than usual, and the inspection of farms was begun earlier than in 1924. (Tables 1 and 2.) As in 1924, the farm reserve of wheat was small, and in most cases it was lightly infested. In fact, infested wheat was found on only 3 of the 43 farms visited, Nos. 8, 18, and 26. On farm 26 hundreds of moths were present in the stored wheat. On farm 34 the wheat had recently been sold and was reported by the owner to have been infested. Stored wheat

[4] KING, J. L. Op. cit.

was found on 12 farms, Nos. 4, 8, 10, 14, 18, 20, 22, 26, 32, 34, 36, and 37. The wheat on farms 10, 14, and 36 was reported to have been fumigated; that on farm 10 was not examined.

As far as stored corn was concerned, conditions were markedly different from those of the previous year. In 1924 the corn crop on most farms did not have time to mature well, and since moth abundance was at a low ebb in the wheat crop of that year, the ripening

TABLE 2.—*Dispersion of the Angoumois grain moth to wheat fields, 1925*

Farm No.	Date of farm inspection and sampling	Sample No.	Probable sources of moths	Estimated distance of sampled shocks from probable sources of moths	Number of emerged moths	Estimated number of kernels in sample	Estimated infestation
				Feet			*Per cent*
1	June 20	1	Corn	200	0	11,400	0.00
		2	do	400	0	11,300	.00
2	do	1	do	75	0	10,900	.00
		2	do	300	0	16,500	.00
3	do	[a] 1	do	200	1	8,800	[b].01
		2	do	600	0	7,100	.00
4	June 22	[a] 1	Corn; wheat screenings	150	3	7,700	.04
		2	do	400	0	8,100	.00
		3	do	500	0	8,300	.00
5	do	1	Straw	150	0	15,900	.00
		2	do	400	0	14,100	.00
		3	do	600	0	14,500	.00
6	do	[a] 1	None	400	0	8,400	.00
		2	do	550	0	10,300	.00
7	do	[a] 1	Corn, straw	250	0	10,000	.00
		2	do	400	0	11,900	.00
		3	do	550	0	10,900	.00
8	do	[a] 1	Wheat	30	4	10,200	.04
		2	do	180	2	8,800	.02
		3	do	330	0	8,900	.00
9	June 23	[a] 1	Corn, straw	50	0	8,900	.00
		2	do	200	0	11,900	.00
		3	do	350	0	8,700	.00
10	do	[a] 1	do	50	0	7,900	.00
		2	do	150	0	10,300	.00
		3	do	250	0	10,200	.00
11	do	[a] 1	Corn	60	0	9,800	.00
		2	do	260	0	7,700	.00
		3	do	760	0	8,500	.00
12	June 26	1	do	100	0	12,700	.00
		2	do	200	0	14,200	.00
		3	do	350	2	16,500	.01
13	do	1	do	150	12	15,300	.08
		2	do	350	0	14,000	.00
		3	do	950	0	13,500	.00
14	do	1	Wheat	50	10	16,200	.06
		2	do	200	6	15,800	.04
		3	do	450	2	17,800	.01
15	do	1	Straw	50	5	14,700	.03
		2	do	200	0	16,300	.00
		3	do	400	16	18,700	.09
16	do	1	Corn, straw	35	21	17,800	.12
		2	do	135	7	18,800	.04
		3	do	335	0	20,500	.00
17	June 27	1	Corn	200	11	13,700	.08
		2	do	350	3	15,300	.02
		3	do	500	0	15,500	.00
18	do	1	Wheat	150	2	14,600	.01
		2	do	300	0	13,700	.00
		3	do	450	0	15,600	.00
19	do	1	None	300	1	12,500	.01
		2	do	450	1	14,900	.01
		3	do	600	[c] 0	16,000	.00
20	do	1	Straw, wheat in litter	100	[c] 0	14,800	.00
		2	do	300	0	17,400	.00
		3	do	400	0	19,100	.00
21	do	1	Straw	1,000	1	15,700	.01
		2	do	1,300	0	17,900	.00
		3	do	1,600	1	16,700	.01

[a] Bearded wheat in this series of samples.
[b] Percentages of less than 0.01 are in each case recorded as 0.01.
[c] On later examination sample was found to have been infested.

TABLE 2.—*Dispersion of the Angoumois grain moth to wheat fields, 1925*—Contd.

Farm No.	Date of farm inspection and sampling	Sample No.	Probable sources of moths	Estimated distance of sampled shocks from probable sources of moths	Number of emerged moths	Estimated number of kernels in sample	Estimated infestation
				Feet			*Per cent*
22	June 27	1	Wheat	300	1	15,200	0.01
		2	do	400	0	14,100	.00
		3	do	500	0	14,600	.00
23	June 29	1	Corn, straw	75	0	16,500	.00
		2	do	225	9	14,900	.06
		3	do	375	2	15,900	.01
24	do	1	Straw	500	4	16,700	.02
		2	do	200	2	16,800	.01
		3	do	300	0	17,000	.00
25	do	1	Corn, straw	100	5	16,600	.03
		2	do	150	[c] 0	16,300	.00
		3	do	400	1	15,200	.01
26	June 30	1	Corn, wheat	350	6	14,400	.04
		2	do	500	14	17,400	.08
		3	do	650	5	17,000	.03
27	do	1	Straw	300	8	14,600	.05
		2	do	450	[c] 0	17,500	.00
		3	do	600	[c] 0	20,100	.00
28	do	1	Straw, wheat in litter	30	18	16,900	.11
		2	do	130	0	15,000	.00
		3	do	230	3	15,400	.02
29	do	1	Corn, straw	1,000	8	14,600	.05
		2	do	1,100	0	17,700	.00
		3	do	1,200	3	16,700	.02
30	do	1	Corn; wheat screenings	150	1	15,600	.01
		2	do	250	8	14,800	.05
		3	do	350	0	14,100	.00
31	July 1	1	Corn	150	6	12,600	.05
		2	do	250	8	16,500	.05
		3	do	350	1	16,900	.01
32	do	1	Straw, corn, wheat	15	4	13,200	.03
		2	do	200	2	16,100	.01
		3	do	[d] 215	1	15,900	.01
33	do	1	Straw	150	8	18,300	.04
		2	do	250	[c] 0	17,400	.00
		3	do	350	0	18,100	.00
34	do	1	Straw, corn, wheat	300	1	15,300	.01
		2	do	400	2	17,700	.01
		3	do	500	10	16,800	.06
35	do	1	None	400	2	15,600	.01
		2	do	600	0	13,700	.00
36	July 2	[a] 1	Straw, wheat	270	3	10,900	.03
		2	do	400	5	10,600	.05
		3	do	500	0	10,200	.00
37	do	[a] 1	Wheat, straw	100	2	11,200	.02
		2	do	200	2	11,800	.02
		3	do	[c] 650	7	12,400	.06
38	do	1	Corn, straw	100	21	11,300	.19
		2	do	250	10	12,800	.08
		3	do	400	11	16,500	.07
39	do	1	do	200	29	13,500	.21
		2	do	300	2	16,600	.01
		3	do	400	0	18,000	.00
40	July 3	1	Straw	75	45	15,800	.28
		2	do	175	7	17,000	.04
		3	do	275	9	16,000	.06
41	do	1	do	75	0	18,900	.00
		2	do	175	4	18,500	.02
		3	do	325	[c] 0	16,200	.00
42	do	[c] 1	Corn	100	5	10,700	.05
		2	do	175	7	11,300	.06
		3	do	250	1	13,400	.01
43	do	1	do	75	0	18,400	.00
		2	do	150	0	17,900	.00
		3	do	225	1	17,600	.01
			Total		425	1,775,900	
			Average	332	3.4	14,321	.02

[a] Bearded wheat in this series of samples.
[c] On later examination sample was found to have been infested.
[d] Distance given from a second probable source of moths.
[e] This sample was 150 feet from the premises of a neighbor.

corn was not exposed to much infestation. The small crop and high price combined to produce a small carry-over. Farmers sold or fed so large a part of their corn that the stocks on hand at the time of wheat harvest in 1925 were usually small. In fact a considerable number of farmers were buying corn to supply their current needs.

Of the 43 farms reported upon in Table 2, 18 had no corn in storage. Nine farms (5, 6, 15, 19, 21, 27, 33, 35, and 41) had no home-grown stored grain of any kind. In some cases small quantities were being purchased from time to time. However, all but 3 of these farms (6, 19, and 35) had wheat straw on them, either baled, piled loose, or scattered in barns, barracks, or barnyards. Field infestations occurred on 7 of the 9 farms—15, 19, 21, 27, 33, 35, 41.

On 5 of the 25 farms that were carrying stored corn, the corn was found to be infested. The condition of the corn on farms 7, 38, 39, and 40 was not observed. Where infestation was seen in corn (farms 2, 3, 13, 26, and 30) it was very light. The small quantity of corn on farm 2 was so lightly infested that the samples showed no field infestation. No barley was found in storage, and oats were being held on but 1 farm, No. 36. No moths were seen in the oats. Summing up, moths were observed in stored grain on 7 of the 43 farms visited in 1925; whereas, in 1924, 27 of the 35 farms inspected had shown infestation. A moth was seen on wheat in the field on farm 13, at a distance of 150 feet from infested corn.

In 1924 definitely infested farms were sought, and only those on which stored grain was found were investigated by sampling the near-by shocked wheat. A more general program was followed in 1925, and samples were taken on farms where no grain was found or where straw constituted the only suspected source of moths. Only wheat straw of the 1924 crop was considered capable of producing moths; rotting straw ricks two or three years old were present on some farms, but these were evidently not in a condition to harbor moths.

Straw was found on 22 of the 43 farms. Baled straw under cover of a roof was present on farms 34 and 40; straw piles were found near the barns on Nos. 5, 7, 9, 15, 20, 21, 23, 27, 29, 33, and 37; straw piles were in the fields on Nos. 24, 25, 28, and 32. Litter was found in yards on farms 10, 16, 36, and 41, and under cover in barns and barracks on Nos. 28 and 38. In the absence of other sources, it seems probable that most of the moths which infested wheat before harvest on farms 15, 21, 24, 27, 28, and 33 came from infested kernels that were present in straw. Wheat screenings were found on farms 4 and 30.

In 1926 harvesting of wheat began in central Maryland on June 30, about nine days later than normal. Farm inspections showed an abundant supply of corn on farms from the good crop of 1925. Moths were observed in stored grain or straw on 23 of the 30 farms examined. The corn on these farms was infested without exception, the infestations appearing to be light except on farms 2 and 11. No moths were seen on farms 1, 9, 24, 26, 28, 29, and 30. (Table 3.)

Wheat was found in storage on seven farms—4, 5, 6, 23, 25, 26, and 30. The quantity of stored wheat was generally small, and only that on farms 4 and 5 was seen to be infested.

Barley was present on two of the farms and rye on one, but no moths were observed in these grains.

Straw was found on 18 of the 30 places visited. There was baled straw on six farms, and moths were observed about such straw on farms 7, 13, and 21. Straw litter was infested on farm 21. Loose straw, in more or less well-made piles, was heaped near the barn on 12 farms and inside the barn on 1 farm.

The amount of wheat present in straw after threshing appears to be by no means negligible with respect to the overwintering of the Angoumois grain moth in wheat kernels. The sprouting of wheat kernels present in outdoor straw piles in Montgomery County, Md., during an 11-day rainy period in August, served to indicate the presence of a considerable quantity of grain. Wheat sprouted in all parts of the piles, and in places thick mats of sprouts appeared. Although baling such straw would be expected to prevent the emergence of most of the moths which develop deep within the bales, kernels occur at or near the surface and in the litter that is shaken from bales during handling and when they are cut open for use.

TABLE 3.—*Dispersion of the Angoumois grain moth to wheat fields, 1926*

Farm No.	Date of farm inspection and sampling	Sample No.	Probable sources of moths	Estimated distance of sampled shocks from probable sources of moths	Number of emerged moths	Estimated number of kernels in sample	Estimated infestation
				Feet			*Per cent*
1	June 24	1	Corn	125	16	10,600	0.15
		2	do	225	0	8,500	.00
		3	do	325	0	10,700	.30
2	do	1	Corn, straw [a]	50	15	7,800	.19
		2	do [a]	200	7	8,100	.09
		3	do [a]	400	0	8,800	.00
3	June 25	1	Corn [a]	150	1	8,400	.01
		2	do [a]	250	5	7,700	.07
		3	do [a]	375	15	6,400	.23
4	do	1	Corn, straw, wheat [a]	200	5	8,100	.06
		2	do [a]	300	5	10,900	.05
		3	do [a]	550	0	10,400	.00
5	July 2	1	Corn, wheat	250	0	11,700	.00
		2	do	375	1	11,800	.01
		3	do	575	4	13,400	.03
6	do	1	Corn	300	0	12,600	.00
		2	do	400	1	13,900	.01
		3	do	550	0	13,800	.00
7	do	1	Corn, straw	150	0	14,200	.00
		2	do	250	0	14,800	.00
		3	do	400	1	12,400	.01
8	do	1	do	15	1	13,700	.01
		2	do	165	1	14,300	.01
		3	do	315	1	14,700	.01
9	July 3	1	do	100	2	12,800	.02
		2	do	250	0	14,300	.00
		3	do	350	0	14,700	.00
10	do	1	do	100	48	14,600	.33
		2	do	200	22	15,100	.15
		3	do	300	0	14,300	.00
11	do	1	Corn	40	50	16,400	.30
		2	do	165	13	16,400	.08
		3	do	340	0	16,600	.00
12	do	1	do	200	0	14,500	.00
		2	do	300	10	13,000	.08
		3	do	400	1	15,700	.01
13	July 7	1	Corn, straw	75	17	9,500	.18
		2	do	175	11	11,600	.09
		3	do	275	3	13,500	.02

[a] Bearded wheat; all other samples beardless.

TABLE 3.—*Dispersion of the Angoumois grain moth to wheat fields, 1925*—Contd.

Farm No.	Date of farm inspection and sampling	Sample No.	Probable sources of moths	Estimated distance of sampled shocks from probable sources of moths	Number of emerged moths	Estimated number of kernels in sample	Estimated infestation
				Feet			*Per cent*
14	July 7	1	Corn	200	5	12,300	0.04
		2	do	300	19	13,300	.14
		3	do	375	1	14,200	.01
15	do	1	Corn, straw	75	0	13,000	.00
		2	do	150	0	13,500	.00
		3	do	250	2	11,900	.02
16	do	1	Corn, barley	100	2	15,300	.01
		2	do	175	0	14,800	.00
		3	do	250	1	16,600	.01
17	do	1	Corn, straw	100	3	12,700	.02
		2	do	200	0	15,000	.00
		3	do	325	36	13,700	.26
18	July 8	1	Corn	125	8	13,600	.06
		2	do	225	15	12,200	.12
		3	do	325	2	14,200	.01
19	do	1	Corn, straw	40	4	13,400	.03
		2	do	140	1	13,400	.01
		3	do	240	4	13,000	.03
20	do	1	Corn	150	0	12,600	.00
		2	do	250	0	16,600	.00
		3	do	375	0	16,200	.00
21	do	1	Corn, straw	50	6	12,900	.05
		2	do	175	13	14,700	.09
		3	do	300	1	14,700	.01
22	July 9	1	do	300	9	13,600	.07
		2	do	400	0	15,500	.00
		3	do	500	0	13,900	.00
23	do	1	do	100	0	12,500	.00
		2	do	225	0	12,000	.00
		3	do	350	0	12,300	.00
24	do	1	Corn	75	0	11,100	.00
		2	do	225	0	12,300	.00
		3	do	325	0	11,600	.00
25	July 10	1	Corn, straw	500	1	16,500	.01
		2	do	600	0	16,500	.00
		3	do	700	0	18,000	.00
26	do	1	do	150	42	15,700	.27
		2	do	250	1	11,900	.01
		3	do	350	3	14,500	.02
27	July 12	1	do	100	15	13,300	.11
		2	do	225	2	14,900	.01
		3	do	325	2	17,400	.01
28	do	1	Corn	200	1	14,700	.01
		2	do	325	0	12,500	.00
		3	do	425	0	15,500	.00
29	July 13	1	do	150	1	14,700	.01
		2	do	250	0	14,100	.00
		3	do	350	0	17,100	.00
30	do	1	Corn, straw	40	0	14,100	.00
		2	do	140	7	11,800	.06
		3	do	240	16	14,100	.11
	Total				479	1,196,600	
	Average			254	5.3	13,296	.04

Corn and wheat appear to constitute a cycle of host materials for the moth. In the fall, when the supply of stored corn on farms is at a minimum, moths fly principally from large stocks of infested wheat to the ripening corn; in the spring and early summer, when the supply of stored wheat is at a minimum, the insects fly principally from the generally well-distributed and abundant stocks of corn to the ripening wheat.

DISTRIBUTION OF INFESTATION IN WHEAT FIELDS

The recorded emergence of moths from samples collected in the fields in 1924 shows clearly that the stored grain or litter examined on each farm was the principal source from which the insects flew to the growing wheat. As shown in Table 1, the number of insects present in the shocked wheat in fields adjacent to stored grain decreased as the distance from the source of moths increased.

In 1924 moths emerged from samples collected 800, 900, and 1,000 feet from stored grain. Even though infested planted grain may have been a source of some moths, it is apparent that the distribution of field infestation arising from such moths would not be correlated with the distance to stored grain in farm buildings. In 1924 field infestation was so correlated, with the exception of that on farm No. 12.

The distribution of the infestation in the field was more irregular in 1925 than in the preceding year, according to the records given in Table 2. In 1925 three samples were taken on nearly all farms visited. Shocks at distances of 1,000, 1,200, and 1,600 feet from stored grain or straw were found to be infested. In some cases, as shown in the table, sample 1 was not so heavily infested as were samples at a greater distance from farm buildings, but the average condition was the same as in 1924; that is, the heaviest field infestations occurred in wheat which was nearest to stored grain, litter, or straw. Several samples, originally recorded as free from infestation, were later found to have been infested, as noted in the third footnote to Table 2.

The 1926 sampling showed widespread field infestations to be present at harvest time in the areas inspected. As in the case of the average results for the two preceding years (Table 4), this infestation decreased, in fields near stored grain and straw, with increasing distance from probable sources of moths.

TABLE 4.—*Summary of location, size of samples, and degree of infestation of shocked wheat, 1924, 1925, and 1926*

Year	Sample No.	Average number of kernels in samples	Average distance from probable sources of moths	Average infestation
			Feet	*Per cent*
1924	1	11,069	173	0.40
	2	12,423	360	.11
	3	11,540	780	.03
1925	1	13,584	189	.04
	2	14,372	338	.02
	3	15,100	485	.01
1926	1	12,897	140	.07
	2	13,180	250	.04
	3	13,810	372	.02

Although moths may fly or be blown considerable distances from sources on neighboring farms, the majority of wheat growers in the districts visited provide for most of the infestation of their own wheat fields by maintaining moth sources on their farms. The absence of

such sources during the period in which the wheat is maturing—from blossoming to harvest—is a condition which farmers should try to maintain.

DEGREE OF INFESTATION IN WHEAT FIELDS

Duhamel du Monceau and Tillet[5] found that infestations were heaviest near towns and mills where there was an abundance of infested grain in storage, and that the insects were much less numerous in wheat fields located in clearings in the forest or in the midst of extensive areas of vineyards. A collaborator reported to them that not more than 6 per cent of the kernels were usually infested at harvest time, even in the most heavily infested fields. In one case, however, 330 kernels out of a sample of 3,000 collected at the time of harvest produced moths, an infestation of 11 per cent. Under favorable conditions these small percentages may increase very rapidly. The same collaborator collected a sample of wheat during the threshing, on September 7, 1761, and found the infestation to be over 98 per cent. The wheat had been harvested July 20, at which time the percentage of kernels containing the various stages of the insect was presumably small.

As shown in Tables 1, 2, and 3, the percentage of infestation of all the samples in 1924 was 0.26, of the samples in 1925, 0.02, and of the samples in 1926, 0.04. The average degree of infestation was smaller for 1925 than for 1924 for several reasons. Proportionately more No. 3 samples, which are ordinarily lightly infested, were collected in 1925. There was less stored grain on the farms at the time of the 1925 harvest, and it was more lightly infested. Finally, as previously noted, some of the late-emerging individuals were not included in the emergence records of 1925. When the quantity of material is large there are practical difficulties which prevent the accurate recording of the emergence of all the moths which are present in the samples as eggs, larvae, and pupae at harvest time.

It should be mentioned that there is probably a varying amount of concentration of oviposition on the exposed heads of shocks, and from these heads samples were taken. The concentration would be expected to vary both with the length of time the wheat had been in the shock when the samples were taken (usually from 1 to 10 days), and with the type of shock. Long, narrow, uncapped shocks, such as are common in southeastern Pennsylvania, allow the moths easy access to nearly all of the heads; the very large shocks sampled in southern Maryland were so built as to expose a comparatively small number of the heads in a field.

Eleven of the farms inspected in 1924 were again examined in 1925. The numbers of these farms are paired as follows, the 1924 number being given first: 4 and 23, 5 and 24, 6 and 19, 9 and 21, 10 and 20, 19 and 14, 21 and 25, 22 and 29, 26 and 26, 31 and 30, 33 and 34. Field infestation occurred on these farms in both years, and two of them, 19 and 14 and 26 and 26, were rather heavily infested both years.

[5] DUHAMEL DU MONCEAU [H. L.], and TILLET [M.]. HISTOIRE D'UN INSECTE QUI DEVORE LES GRAINS DE L'ANGOUMOIS; AVEC LES MOYENS QUE L'ON PEUT EMPLOYER POUR LE DÉTRUIRE. 314 p., illus. Paris, 1762.

Of the farms visited in 1926, nine had been inspected in one or both of the preceding years. Every sampling of shocked wheat on these farms showed that it was infested. The wheat fields near stored grain or straw on farms 18, 19, 22, and 25 were found infested for three years in succession.

Although moths were not observed in grain or straw on farms 1, 9, 26, 28, 29, and 30, the samples showed that the shocked grain was lightly infested on each of these farms. Conversely, on farms 20 and 23, where moths were seen in stored corn, none emerged from the field samples of wheat, although a light preharvest infestation was probably present. Even a more thorough method of sampling than that used by the writers might not reveal the presence of a few insects scattered in a wheat field.

The average harvest-time infestation of wheat in the field was low in fields near probable moth sources in 1926, but the percentage of infestation, 0.04, was twice the average for 1925. However, as shown in Table 4, the 1926 samples were taken somewhat nearer to stored grain and straw than were the samples collected the year before.

The method of arriving at the percentages of infestation was as follows: The wheat in each one-third sample was threshed separately and cleaned with a fan. It was then measured in a graduate and one-tenth of its bulk removed, cleaned of broken and diseased kernels, and counted. Ten times the resulting count gave the number of kernels in the one-third sample. The size of the samples is given in Tables 1, 2, and 3. The percentages of infestation, shown in the last column, were obtained by dividing these figures into the corresponding numbers of emerged moths.

The data referring to the size, distance from moth sources, and percentage of infestation of the samples are summarized in Table 4. The 1924 samples were smaller than those of 1925 and 1926 chiefly because in 1924 an epidemic of wheat scab, *Gibberella saubinetii* (Mont.) Sacc., shriveled from 2 to 30 per cent of the wheat in the samples. This disease appeared to be absent from the 1925 and 1926 material. The average sample in 1924 contained 501 heads of wheat, which averaged 23 good kernels per head; no counts of heads were made in 1925 and 1926.

In the several districts visited in 1925 and 1926 no striking differences in the moth situation were observed.

Although the percentages of infestation in the samples appear small, they indicate the presence of a very considerable moth population in the fields at harvest time, when the number of all stages of the insect per acre are considered. The average infestation in 1924 was 0.26 per cent, yet, as shown below, this means that standing wheat in the vicinity of moth sources was infested to the extent of about 28,500 of the insects per acre.

The harvest-time moth population per acre may be estimated as follows: The number of kernels in 3 one-half pints of wheat from the 1924 samples was counted and found to be, respectively, 5,170, 5,434, and 5,637, an average of 5,413 kernels per half pint. This is at the rate of 21,652 kernels per quart, or 692,864 per bushel. In 1924 the average production of wheat per acre in Maryland was 15.8 bushels.[6] Multiplying this yield by the number of kernels that

[6] UNITED STATES DEPARTMENT OF AGRICULTURE. AGRICULTURAL STATISTICS. BREADGRAINS. U. S. Dept. Agr. Yearbook 1924: 563. 1925.

1 bushel is estimated to contain gives 10,947,000 kernels per acre, 0.26 per cent of which is, in round numbers, 28,500, the average number of insects per acre at harvest time in fields near stored grain. The highest infestation recorded in 1924 was 2.06 per cent, which would indicate the presence of 225,000 moths per acre. Assuming that half of these were females and that each would produce on an average 100 eggs (a conservative estimate), the resulting progeny from the moths in an acre of wheat at harvest time would theoretically number about 11,000,000; equivalent to 100 per cent infestation. The potential importance of preharvest infestation is therefore clear. Given unusually hot weather in June and July and plenty of unthreshed wheat, a light infestation at harvest may result in the presence of enormous numbers of moths a few weeks later. Back and Cotton [7] recorded infestations as high as 90 per cent during 1922 in Montgomery County, Md., where threshing had been much delayed, as compared with an infestation of about 2 per cent at harvest time.

DISCUSSION AND CONCLUSIONS

Several sources of error in the material which forms the basis for this report have been suggested. It is not always possible, in a brief inspection, to determine whether or not a suspected source of moths is infested or has produced the insects during the maturing of the wheat in near-by fields. Especially is this true of corn and straw. The presence of straw piles was not recorded in 1924. It is necessary to collect samples on a succession of days, and the difference in the length of time that the sampled heads have been exposed to the oviposition of the moths reduces somewhat the comparableness of the data. Furthermore, when a large quantity of material is involved, it is practically impossible to obtain an entirely accurate record of the emergence of moths from the sample lots of wheat heads. After making allowance for these irregularities, the writers believe that the information here presented constitutes material from which useful conclusions may be drawn. These conclusions are: (1) The principal moth sources which cause preharvest infestation of wheat in the eastern wheat region are ear corn and wheat in straw, bins, and litter from mows; (2) field infestation of the wheat crop in fields near sources of moths is the rule rather than the exception, and the percentage of infestation decreases as the distance from moth sources increases; (3) the percentage of infestation in the field is low, but an infestation of 0.26 per cent indicates a moth population of about 28,500 per acre (owing to the rapidity of increase of the Angoumois grain moth, these early infestations develop into destructive outbreaks [8] when weather conditions are favorable); (4) if preharvest infestation were eliminated, the severe and widespread damage now caused by the insect would be a thing of the past.

[7] Back, E. A., and Cotton, R. T. control of insect pests in stored grain. U. S. Dept. Agr. Farmers' Bul. 1483, 30 p., illus. 1926.

[8] The writers have considered the causes of moth outbreaks in the following article: Simmons, P., and Ellington, G. W. the causes of outbreaks of the angoumois grain moth. Jour. Econ. Ent. 18: 309-320, illus. 1925.

TWO HYMENOPTEROUS PARASITES OF AMERICAN JOINTWORMS[1]

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INTRODUCTION

This paper gives an account of the life histories of two important parasites of species of Harmolita. They are hymenopterous parasites of the superfamily Chalcidoidea and have been mentioned in literature, though no detailed accounts of their life histories as parasites of the genus Harmolita have ever been recorded. The observations on which this dissertation is based were made at the United States Entomological Laboratory, Charlottesville, Va., during 1919, 1920, and 1921. The adult parasites used in the experiments recorded herein were obtained from material collected in various localities and kept through the winter in the Charlottesville laboratory under as nearly normal conditions as could be provided.

The methods of rearing followed were, for the most part, similar to those described and illustrated in a previous paper.[2] The parasites here discussed frequently deposited eggs more freely in smaller cages than in those used for certain other parasites. These cages are described in another part of this paper.

EUPELMINUS SALTATOR LINDEMAN[3]

This species (fig. 1) was first described from Russia by K. Lindeman[4] in 1877 under the name *Euryscapus saltator*. It was later placed in the genus Mira Schellenberg, which was regarded as synonymous with Euryscapus Foerster.

In 1918 the late W. R. McConnell,[5] of the division of cereal and forage insects of the Federal Bureau of Entomology, gave an excellent account of the life history of this species as a parasite of the Hessian fly. At the suggestion of A. B. Gahan he used the name *Eupelminus saltator* for the parasite. This was the first published record of this parasite in American literature.

DISTRIBUTION

Lindeman[6] reports that this species from Moscow, Russia, is probably widespread in Europe as a parasite of the Hessian fly, although apparently never abundant. McConnell[7] observed it as a

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[1] Received for publication Nov. 29, 1926; issued April, 1927. Mr. Poos resigned on Mar. 15, 1926.

[2] PHILLIPS, W. J., and POOS, F. W. LIFE-HISTORY STUDIES OF THREE JOINTWORM PARASITES. Jour. Agr. Research 21: 405–426, illus. 1921.

[3] Family Encyrtidae, subfamily Eupelminae.

[4] LINDEMAN, K. DIE PTEROMALINEN DER HESSENFLIEGE (CECIDOMYIA DESTRUCTOR SAY). Soc. Imp. Nat. Moscow Bul. (n. s.) 1: 190–191, illus. 1887.

[5] MCCONNELL, W. R. EUPELMINUS SALTATOR LINDM. AS A PARASITE OF THE HESSIAN FLY. Jour. Econ. Ent. 11: 168–175, illus. 1918.

[6] LINDEMAN, K. Op. cit.

[7] MCCONNELL, W. R. Op. cit.

Journal of Agricultural Research,
Washington, D. C.

Vol. 34, No. 5
Mar. 1, 1927
Key No. K-186

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parasite of the Hessian fly, though not abundant, in 9 localities in Pennsylvania, 2 localities in Maryland, and 2 localities in Virginia. As a parasite of the genus Harmolita the writers have records of its

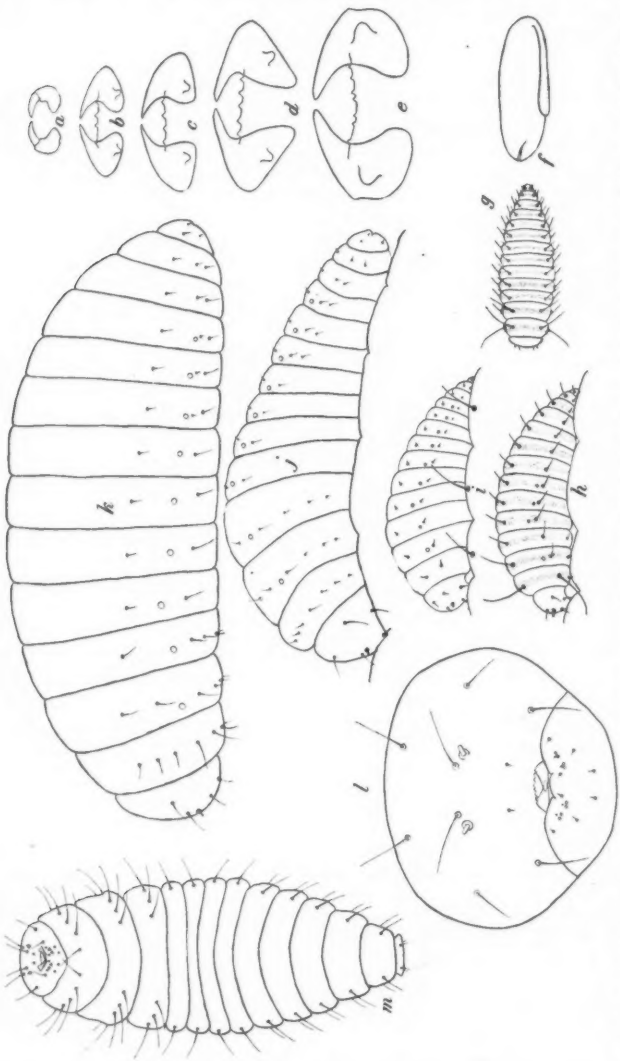

FIG. 1.—*Eupelmus allynii*: *a*, Mandibles of first-instar larva; *b*, same of second-instar larva; *c*, same of third-instar larva; *d*, same of fourth-instar larva; *e*, same of full-grown larva; *f*, egg; *g*, first-instar larva soon after hatching (dorsal view); *h*, first-instar larva just before molting (lateral view); *i*, second-instar larva (lateral view); *j*, third-instar larva (datero-ventral view); *k*, fourth-instar larva (datero-dorsal view); *l*, head of full-grown larva, showing position of sensory hairs and antennae and the sensoria of the mouth parts; *m*, prepupa (ventral view). All greatly enlarged

occurrence from the following States: New York, Ohio, Michigan, Virginia, Pennsylvania, Oregon, Illinois, and North Dakota. This parasite is very widely distributed and probably occurs throughout

the wheat-growing regions of the United States. As a parasite of Harmolita, *Eupelminus saltator* has never been found very abundant except in a few instances when it seemed to be the most important parasite.

HOSTS

The writers have reared *E. saltator* abundantly from several species of Harmolita and are unable to state definitely which species it prefers as a host. It has been reared from the following field collections: From galls of *Harmolita tritici* Fitch, in wheat from New York, Ohio, Michigan, and Virginia; from galls of *H. vaginicola* Doane, in wheat from New York, Pennsylvania, Ohio, Michigan, and Oregon; from galls of *H. hordei* Harris, in barley from New York; from a species of Harmolita in *Agropyron tenerum* Vasey, from North Dakota; from galls of *H. atlantica* Phillips and Emery, in *A. repens* Beauv. from New York; from galls of *H. festucae* Phillips and Emery in *Festuca elatior* L., from New York and Ohio; from *H. maculata* Howard, in cheat (*Bromus secalinus* L.) from New York, Ohio, and Virginia; from *H. dactylicola* Phillips and Emery, in *Dactylis glomerata* L. from New York, Pennsylvania, Ohio, and Michigan; from *H. albomaculata* Ashmead, in timothy from New York, Pennsylvania, Ohio, and Michigan; from *H. elymi* French, in a species of Elymus from Ohio and Michigan; and from galls of Harmolita, in a species of Elymus from Illinois and North Dakota.

Eupelminus saltator deposited eggs freely upon *Harmolita tritici* Fitch, *H. vaginicola* Doane, *H. grandis* form *grandis* Riley, *Eurytoma* spp., *Eupelmus allynii* French, *Ditropinotus aureoviridis* Crawford, *Homoporus chalcidiphagus* Walsh and Riley, and *Phytophaga destructor* Say, when confined in cages. Occasionally this parasite deposited many eggs in empty cells in those cages where there happened to be only a few *H. tritici* larvae and numerous empty cells. Upon one occasion *E. saltator* deposited eggs in the center of green wheat stems which were about ready to head, although no species of Harmolita or Phytophaga were present in this cage. In some cage experiments *E. saltator* deposited eggs in the cells of old galls of *H. tritici* of the previous year in preference to new galls in green stems of wheat when both were present in the same cage. In another instance an egg was deposited in a piece of wheat straw near the point where a puparium of a Hessian fly was located. While the egg was within the straw and near the puparium, the young larva would not have been able to feed upon its intended host.

Eggs of *Eupelminus saltator* which were found deposited upon dead adults of *Harmolita tritici* and upon pupae of *Eupelmus allynii* were transferred with their hosts from the Harmolita cells to glass cell slides. The larvae from these eggs, however, were unable to complete their development upon such hosts. Eggs were often dissected from cells of *H. tritici* where they had been deposited upon larvae of species of Eurytoma. When these eggs were placed in glass cell slides upon their hosts, the very active larvae of Eurytoma frequently crushed the eggs placed upon them, although this was not always the case.

McConnell[8] found *Eupelminus saltator* to be a primary parasite of the Hessian fly, attacking externally both larval and pupal hosts

[8] McConnell, W. R. Eupelminus saltator Lindm. as a parasite of the Hessian fly. Jour. Econ. Ent. 11: 168–175, illus. 1918.

inside the puparium. He also proved that it may be a secondary parasite of the fly by rearing an individual from a puparium which was found to be filled with cocoons of a species of Polygnotus. *Eupelminus saltator* is ordinarily a primary parasite of Harmolita, but when other parasites are present in abundance it can just as easily maintain itself as a secondary parasite.

No extensive experiments were carried on to determine whether *Eupelminus saltator* preferred Harmolita to the Hessian fly, but in a few instances several adults in cages deposited eggs in cells of *Harmolita tritici* in preference to puparia of the Hessian fly. Upon one occasion a female was observed to oviposit in cells of *H. tritici*, and upon hatching the young larvae were reared upon their hosts in glass cell slides; when adults emerged from these cell slides they were induced to deposit eggs within the puparia of the Hessian fly; those eggs were then removed to glass cell slides, allowed to hatch, and reared to adults upon the pupae of the Hessian fly. These progeny were in turn bred back upon *H. tritici* by the same method. The adults used in these experiments were saved for comparison and were found to be identical in external appearance. These experiments proved that *E. saltator* is entirely able to maintain itself upon either Harmolita or the Hessian fly, which characteristic adds very much to the value of this parasite as an enemy of the two most important wheat pests in the United States.

Eupelminus saltator has been found to have a wider range of hosts than any other parasite of Harmolita, with the possible exception of *Eupelmus allynii*. This wide range of hosts, consisting of various species of Harmolita and their parasites, and the Hessian fly and its parasites, would seem to make this species a particularly desirable and valuable parasite. *E. saltator* will probably increase and aid greatly in reducing the numbers of either of these hosts when they become very abundant.

EGG

The eggs (fig. 1, *f*) are well described by McConnell[9] as follows:

> They are white in color. The chorion is thin and elastic, with a smooth and shining surface. They are ellipsoidal in form with a large pedicel at the cephalic pole and a slender flagellum at the caudal pole * * *. The pedicel is about half as long as the egg and is usually folded back along the side of the egg, its tip being recurved forward, but it may be bent and twisted in various ways. The flagellum at the posterior pole is about half as long as the pedicel and usually lies against the posterior surface of the egg.

The average size of three eggs was found to be 0.3966 mm. in length and 0.1508 mm. in greatest width. The period of incubation for 40 eggs ranged from 1.5 to 4 days and averaged 2.3 days. In August, 1921, when weather conditions seemed normal, the incubation period of 13 eggs averaged 2.1 days. Observations on the process of hatching showed that occasionally the mandibles were thrust out with a vicious stroke, as though trying to cut the chorion. The chorion is ruptured at the base of the pedicel, at which point the larva wriggles out of the eggshell.

The eggs are always deposited on the outside of the host. Some seem to cling lightly to the host and others are frequently fastened to the wall of the Harmolita cell by means of a delicate, fibrous,

[9] McCONNELL, W. R. Op. cit.

netlike structure which is apparently woven from fine white threads. This covering is similar to that of *Eupelmus allynii*, which was described and illustrated by the writers in a previous paper.[10] Not uncommonly four or five eggs, and sometimes more, have been found in one Harmolita cell. In such cases the covered eggs always had a separate, individual covering, although these coverings were usually attached to each other. No cases were observed where several eggs were found under a single cover. The eggs were held securely in place as the coverings were usually fastened down rather firmly all around the edges.

Numerous infertile eggs were found in the breeding cages, a large percentage of which had the weblike covering woven over them. Such conditions may have been due to the fact that the adults were exposed to unfavorable environment, or that they did not receive the proper food. Only those eggs which presented a well-rounded normal appearance and were apparently viable were used in the experiments or removed to glass-cell slides where they could be under close observation.

In describing the larvae all the sensory hairs for the head but only those on one-half of the body were recorded. However, the sensory hairs on only one side of the head are figured except where a full front view is given. This should be kept in mind when reading the descriptions. All drawings were made with a camera lucida from living specimens and consequently all could not be drawn from exactly the same angle. While an attempt was made in every case to get a full lateral view, it was impossible, in a few instances, to do so.

LARVA

The larva of *Eupelminus saltator* falls in Parker's[11] Group VI, but differs slightly from his description of a species of Eupelmus. There are only four pairs of large sensory hairs on the head instead of five; all of the abdominal segments have on each side two large sensory hairs, without exception, whereas Parker mentions only one for the sixth segment and none for the tenth.

First Instar

The shape (fig. 1, *g*, *h*) is typical for Parker's[12] Group VI. The color is the translucent whitish; the segmentation is very distinct; the head is brownish and heavily chitinized; the head and body bear numerous sensory hairs of varying length.

In outline the head is elbow-shaped, and reminds one somewhat of the profile of the beak of a vulture; it is approximately as wide as thick but distinctly longer than wide; and is brownish in color and highly chitinized. There are two antennae, approximately three times as long as broad, with only one segment. The head bears eight rather prominent sensory hairs arranged as follows: A pair just above and just inside the antennae, a pair just above and a pair just back of the mandibles; and one sensory hair near the center of each lateral face. The hairs on one side of the head only are illustrated

[10] Phillips, W. J., and Poos, F. W. Life-history studies of three jointworm parasites. Jour. Agr. Research 21: 405-426, illus. 1921.
[11] Parker, H. L. Recherches sur les formes post-embryonnaires des Chalcidiens. Ann. Soc. Ent. France 93: 261-379, illus. 1924. (Thèse Univ. Paris.)
[12] Parker, H. L. Op. cit.

(fig. 1, *h*). The mouth is situated on the ventral side at the apex of the head and is surrounded by a chitinized ring; the mandibles are heavily chitinized, rather long and slender, somewhat sickle-shaped, and dark brown. The sensory organs on the labrum and labium are too obscure to place with certainty.

The body is composed of 13 segments, the greatest diameter of the larva being at about the first or second abdominal segment, from which point the body tapers gradually, being very pointed posteriorly. Each thoracic segment bears on each side three sensory hairs; the dorsal and lateral ones of the first segment are the longest and coarsest of any of the body setae; the dorsal setae of the second segment are somewhat smaller, while the remaining body setae are about of a uniform size, with the exception of the ventral setae, which are smaller. Sensory hairs are arranged as follows: A lateral row the full length of the body just below the spiracles, a tergal row likewise the full length of the body, and a sternal row in the thoracic region only. Around each segment is a rather distinct band of spicules. There are four pairs of open spiracles, one on the second thoracic and one on each of the first, second, and third abdominal segments.

In the newly hatched larva the head is about as broad as the abdominal segments, but just before molting it is very noticeably narrower.

The average length of 3 larvae was 0.5018 mm., the average greatest width 0.1605 mm.

Second Instar

After the first molt the larva has a very different appearance. It is perhaps more delicate in this stage (fig. 1, *i*) than in any other. The setae are very inconspicuous.

The head is somewhat intermediate in shape between that of the first-instar larva and the full-grown larva; it is very feebly chitinized, whitish; and it bears 10 small sensory hairs arranged as follows: A pair just above and a pair just back of the mandibles; a pair between and just above the antennae; a pair submedian on the dorsal posterior part of the epicranium, and one hair near the center of each lateral face. The antennae are smaller than in the previous instar, about twice as long as broad; the mandibles are triangular in outline and feebly chitinized; the sensory organs of the labium are very inconspicuous and no attempt was made to place them. The labrum bears several heavily chitinized lobes. The setae in this instar are much less conspicuous than in the first instar. The thoracic and abdominal segments bear on each side two sensory hairs, arranged as indicated in Figure 1, *i*. There are nine pairs of open spiracles in this instar.

The average length of five larvae was 1.078 mm., and the average width was 0.3325 mm.

Third Instar

Color and general shape (fig. 1, *j*) about the same as in the previous instar. The setae are more prominent on the head in this instar but approximately the same on the body.

The head is shaped very much as in the full-grown larva and is more strongly chitinized than in the second instar; there are 10 rather prominent setae on the head, arranged as in the second instar; the antennae are about twice as long as broad; the mandibles are tri-

angular in outline and rather heavily chitinized. No attempt was made to place the sensory organs of the labium; the labrum bears several heavily chitinized denticles (fig. 1, *c*). Setae on the body are slightly more conspicuous than in the preceding instar and more numerous, arranged on each side of the body as follows: Seven setae on the first thoracic segment, 6 on the second, and 5 on the third; 2 setae on each of the first, second, third, and fourth abdominal segments; 3 setae on each of the fifth, sixth, seventh, eighth, and ninth abdominal segments; the tenth abdominal segment bears two setae on the upper lobe and one on the lower. There are nine pairs of open spiracles in this instar.

Three larvae averaged 1.47 mm. in length and 0.49 mm. in greatest width.

Fourth Instar

The color and general shape (fig. 1, *k*) are quite similar to the color and general shape of the previous instar. The setae throughout are more conspicuous than in the previous instar.

The head is shaped as in the full-grown larva and rather strongly chitinized; there are eight rather prominent setae and two smaller setae on the head arranged as follows: A pair of small setae just above the labrum; a pair of prominent setae between and slightly above the level of the antennae; a pair submedian on the dorsal posterior part of the epicranium; one near the center of each lateral face and slightly above the plane of the antennae; one on each side in about the same plane as the mandibles and laterad of them. The antennae are about twice as long as broad; the mandibles are triangular in outline and rather heavily chitinized. No attempt was made to place the inconspicuous sensoria on the labium; the labrum bears four or five heavily chitinized denticles (fig. 1, *d*). Setae on the body are more conspicuous than in the third instar, of equal number and in the same relative position. The illustration (fig. 1, *k*) shows the latero-dorsal aspect of the larva; some of the body setae do not show very well, and only four of those on the head could be shown. There are nine pairs of open spiracles.

Three larvae of the fourth instar averaged 1.75 mm. in length and 0.5833 mm. in greatest width.

Full-Grown Larva

This is cylindrical, tapering toward each extremity (fig. 2). There are 13 distinct segments in addition to the head; the head is almost hemispherical; the larva is translucent-whitish except in the mandibular region where it is brownish. The head is narrower than the body and the mouth parts point downwards. The antennae are about twice as long as broad, unsegmented. There are 8 prominent and 2 very small sensory hairs or setae on the head arranged as follows: 2 small ones just above the labrum; 2 prominent sensory hairs between and slightly above the level of the antennae; 2 submedian on the dorsal posterior part of the epicranium; 1 near the center of each lateral face and slightly above the plane of the antennae; 1 lateral to each mandible and about in the same plane. The labrum is convex, heavily chitinized and usually bears seven prominent denticles. The ventral mouth parts form a fused region which anteriorly is tri-

lobed, corresponding to the component median labial, and the two lateral maxillary regions. This fused region bears 20 sensory hairs and organs arranged as follows: Two groups of sensory organs with 3 in each group in each maxillary region, 4 of which organs are ring-shaped, and 2 are very small sensory hairs; in addition there are 2 more prominent sensory hairs laterally of these groups in each maxillary region, and 4 sensory hairs on the median lobe or labial region (fig. 1, *l*). The mandibles are heavily chitinized, reddish brown, and triangular in outline. The first thoracic segment bears on each side 7 long hairs, the second 6, and the third 5; the first, second, third, and fourth abdominal segments each bear 2 hairs; the fifth, sixth, seventh, eighth, ninth, and tenth abdominal segments, each 3 hairs. These hairs are arranged as follows: A tergal row and a spiracular or lateral row the full length of the body and an additional lateral row on the fifth, sixth, seventh, eighth, and ninth abdominal segments, just below the lateral row; the tenth segment has on each side 2 setae on the upper lobe and 1 on the lower. On the thorax there are, in addition to the lateral and tergal rows, 3 ventral or sternal hairs to each segment, 2 tergal hairs on the first thoracic and 1 on the second segment. There are 9 open spiracles. Usually

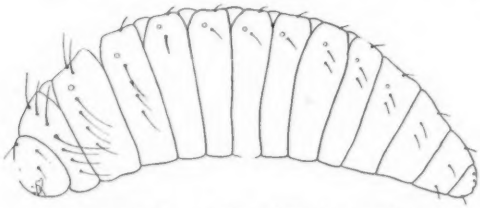

FIG. 2.—Full-grown larva of *Eupelminus saltator*

there are about 8 dorsal folds between the segments, beginning at the interval between the first and second thoracic segments.

Three full-grown larvae averaged 2.601 mm. in length and 0.863 mm. in greatest width.

The manner of feeding and locomotion is similar to that of other chalcidoid parasites of the genus Harmolita. The first larval instar often feeds with only its head touching its host. Larval development of 106 individuals observed in glass cell slides required from 5 to 19 days and averaged 9 days. The period of time individuals remained as mature larvae before pupating varied from 2 to 28 days, and the average for 82 individuals observed was 6.02 days. Many larvae became full grown in glass cell slides but died before pupating. Some of these individuals remained in apparently good condition for a period of over 18 months; after this time they began to contract, lost their normal appearance, and at the end of about 5 more months, when they were about one-third their normal size, died. The larvae of this species are very active and feed without being easily disturbed. They are cannibalistic; although as many as 10 eggs have been found in one Harmolita cell, in cage experiments, never more than one individual completed its development upon a single host larva, which always seemed to provide sufficient food for the parasite to develop fully. The size of the adult parasite was observed to vary

proportionately with the amount and condition of the food supply. In cage experiments, undersized adults could not be induced to oviposit.

PREPUPA

The prepupal or final developmental period of the full-grown larva (fig. 1, *m*) of 47 individuals of this species ranged from 1 to 3 days, the average being 1.4 days. No excrement is voided by the larva until the prepupal stage is entered upon, when a considerable amount is voided, and the prepupa becomes pure white in color and contracts both in length and width. The third thoracic and the first, second,

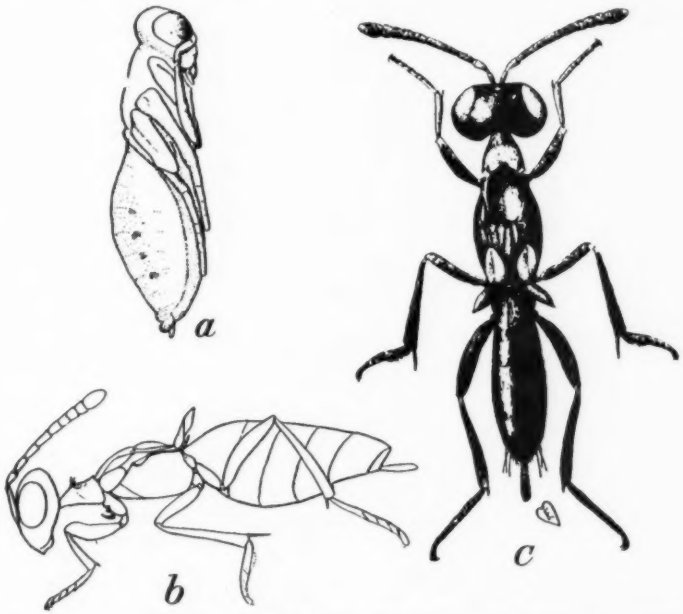

FIG. 3.—*Eupelminus saltator*: *a*, Lateral view of pupa; *b*, dorsal, and *c*, lateral views of adult. (McConnell)

and third abdominal segments become much shorter. The arrangement of the setae remains as described in the earlier development of the full-grown larva. Actual measurement of two prepupae gave an average length of 2.10 mm. and the greatest width averaged 0.805 mm.

PUPA

When first formed the pupa (fig. 3, *a*) is pure white but gradually turns to a light or reddish brown, which approaches the color of the adult. The pupa is slightly concave ventrally; the head is slightly wider than the thorax, the average greatest width of 7 individuals being 0.71 mm. The average length of these same 7 individuals was 2.57 mm. The duration of the pupal period of 86 individuals observed varied from 7 to 13 days and averaged 9.28 days.

ADULT

No males have been found to occur in this species. The females pass the winter as full-grown larvae in the cells of the Harmolita. In Virginia adults of the first generation begin to emerge in May. The adults of *Eupelminus saltator* (fig. 3, *b*, *c*) are easily distinguished from all other known parasites of Harmolita because they do not possess functional wings. They are unable to fly but are able to leap rapidly many times in succession. In most instances they were observed to walk and jump toward the light. In cages the adults were fed a weak sugar solution, which added greatly to their length of life. The adults are very active, and, in cages, travel up and down the straws, stroking them with the antennae, which are bent forward and downward and kept in constant vibration, as though searching for a suitable place to oviposit. The manner of oviposition is the same as that described for *Eupelmus allynii* in a previous paper [13] and the process usually requires several minutes. Sometimes oviposition was much more readily obtained in shell vial cages 30 by 100 mm. in size containing galls of *H. tritici* than in larger cages described in a previous paper.[14] When *H. grandis* form *grandis* or *H. maculata* were used as hosts, oviposition was often more readily obtained by using a 2 by 12 inch glass cylinder cage than by using larger cages of this type.

Longevity experiments in 1920 showed that eight individuals lived from 16 to 38 days, or an average of 26 days, when kept under the most favorable conditions.

The preoviposition period of eight adults of *Eupelminus saltator* ranged from 3 to 19 days and averaged 7.37 days. When hosts are abundant the average preoviposition period in the field is probably not over 3 to 5 days. Of the eight females referred to above, the maximum number of eggs deposited by a single individual was 26, while one female deposited only 3 eggs; the average for the eight females was 10.7 eggs. As many as 10 eggs were obtained from one female in one day. In 1921 one individual under observation lived for a period of 51 days and deposited 30 eggs; another lived 37 days and deposited only 1 egg; while still another lived 27 days and did not deposit any eggs.

During 1919 six generations of *Eupelminus saltator* were reared in the laboratory, from May to October. The period of time required to develop from the egg to the adult during this breeding season varied from 18 to 43 days. The average for eighty-two individuals under observation was 23.5 days. Low temperatures during the spring and fall seemed to retard development considerably, as might be expected. Furthermore some full-grown larvae remained in the cell slides until the following spring before they changed to adults; this, too, in spite of the fact that apparently every condition favorable for development had been met, since other larvae of the same generation and under the same conditions developed normally. Such retarded larvae would wriggle vigorously when touched and seemed normal in every way except for the period of estivation that seemed necessary for them.

[13] PHILLIPS, W. J., and POOS, F. W. LIFE-HISTORY STUDIES OF THREE JOINTWORM PARASITES. Jour. Agr. Research 21: 405–426, illus. 1921.

[14] PHILLIPS, W. J., and POOS, F. W. Op. cit.

ERIDONTOMERUS ISOSOMATIS [15]

Stictonotus isosomatis Riley, U. S. Dept. Agr., Rpt. Ent. 1881–2, p. 186.
Stictonotus isosomatis Howard, U. S. Dept. Agr., Bur. Ent. Bul. 5 (old series), 1885, p. 45.
Merisus isosomatis Cresson, Syn. Hym. Amer. North of Mexico, 1887, p. 242.
Semiotellus isosomatis Dalla Torre, Cat. Hym., v. 5, 1898, p. 211.
Eridontomerus primus Crawford, Journ. N. Y. Ent. Soc., v. 15, 1907, p. 179.
Merisus isosomatis Viereck's Hym. Conn., Bul. 22, Conn. Sta. Geol. and Nat. Hist. Surv., v. 3, 1916, p. 478 (description).

This species was first described, both male and female (fig. 4), in 1881 by C. V. Riley as *Stictonotus isosomatis* from material received from J. K. P. Wallace, of Andersonville, Tenn. A. B. Gahan[16] in 1920 published a paper giving the complete synonymy of the species as it appears above.

DISTRIBUTION

This parasite is very widely distributed and probably occurs throughout all the wheat-growing regions of the United States. As a parasite of the genus Harmolita the writers have records of it from the following States: Massachusetts, New York, Pennsylvania, Ohio, Michigan, Indiana, Illinois, Virginia, Kentucky, and Arizona.

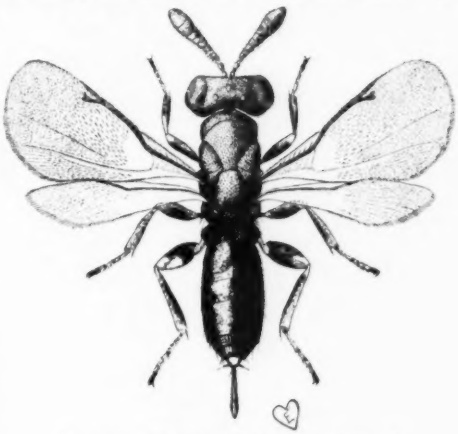

FIG. 4.—Adult female of *Eridontomerus isosomatis*

HOSTS

In the field this species has been found most abundantly as a parasite of *Harmolita maculata* Howard, and has been reared from collections of cheat (*Bromus secalinus* L.) from Massachusetts, New York, Pennsylvania, Ohio, Michigan, Indiana, Illinois, Virginia, and Kentucky. The writers have records of rearings from the following field collections: From galls of *H. festucae* Phillips and Emery in *Festuca elatior* L. from New York, Ohio, and Virginia; from *H. grandis* form *grandis* Riley, in wheat from Virginia; from galls of *H. vaginicola* Doane, in wheat from Michigan; from collections of wheat from Arizona; from galls of *H. atlantica* Phillips and Emery, in *Agropyron repens* Beauv. from New York; from a species of Harmolita in an Agropyron from Michigan; from *H. websteri* Howard in rye from Pennsylvania and Virginia; from *H. dactylicola* Phillips and Emery, in *Dactylis glomerata* L. from New York, Pennsylvania, Ohio, and Michigan; from galls of *H. secalis* Fitch, in rye from Virginia; from *H. albomaculata* Ashmead, in timothy from New York, Pennsylvania, Ohio, Michigan, Indiana, and Virginia; from species of Harmolita in species of Elymus from Virginia.

[15] Family Callimomidae, subfamily Monodontomerinae.
[16] GAHAN, A. B. ON THE IDENTITY OF SEVERAL SPECIES OF CHALCIDOIDEA (HYMENOPTERA). Ent. Soc Wash. Proc. 22: 235–236. 1920.

In cages, the females of *Eridontomerus isosomatis* showed no host preference between *Harmolita maculata* and *H. grandis* form *grandis*. The larva of *H. tritici* Fitch was successfully used as a host for this parasite in glass cell slides. *E. isosomatis* will probably parasitize any of the various species of Harmolita, though it seems to prefer the center-of-stems forms. It has been observed to parasitize individuals of its own species, and though it is usually a primary parasite it undoubtedly becomes secondary when the Harmolita are heavily parasitized.

EGG

The egg (fig. 5, *f*) is grayish white in color and opaque. It is elongate, kidney-shaped; there is a nipplelike process at each pole; the entire surface is covered uniformly with spicules with the exception of the nipplelike process at the posterior pole. The average length of six eggs was 0.5026 mm. and the greatest width was 0.1179 mm. The eggs are deposited in the Harmolita cells external to the host larva, either directly upon the host or in close proximity to it.

LARVA

FIRST INSTAR

This larva (fig. 5, *g*, *h*) belongs to Parker's[17] Group VI. It is cylindrical in shape, tapering slightly towards each extremity; translucent-whitish; segmentations very distinct; head brownish; the head and body are covered with numerous sensory hairs; the sensory hairs on anterior part of body are much more prominent.

Head (fig. 5, *h*) viewed laterally is somewhat elbow-shaped, about as wide as thick, but longer than wide; brownish in color, heavily chitinized; it bears two antennae, apparently twice as long as broad and with only 1 segment; the head also bears three pairs of fairly prominent setae or sensory hairs arranged as follows: A pair just above the labrum, a pair just above and between the antennae, and one on each lateral face. The mouth is situated on the ventral side at the apex of the somewhat elbow-shaped head; the mandibles are sickle-shaped, heavily chitinized, and dark brown (fig. 5, *a*).

The body is composed of 13 segments about equal in length; it tapers only slightly anteriorly, more posteriorly. Each thoracic segment bears on each side 3 very prominent setae, and each abdominal segment bears 2 setae on each side; the setae in the thoracic region are long, coarse hairs, and those on the remaining body segments gradually diminish in size, until those of the last two segments are almost invisible. The setae are arranged as follows: A tergal row and a spiracular or lateral row the full length of the body; in addition there is a ventral or sternal row in the thoracic region. There is a band of spicules around each segment, but they are not present in any of the succeeding instars. Four pairs of spiracles open upon the surface; there seems to be a fifth pair on the third thoracic segment, although it was impossible to be sure that there was an external opening.

SECOND INSTAR

The larva (fig 5, *i*) now has a very different appearance. It resembles neither the first instar nor the full-grown larva. The head

[17] PARKER, H. L. RECHERCHES SUR LES FORMES POST-EMBRYONNAIRES DES CHALCIDIENS. Ann. Soc. Ent. France 93: 261-379, illus. 1924. (Thèse, Univ. Paris.)

capsule is not so highly chitinized nor are the sensory hairs so prominent as in the first instar; besides, the band of spicules about each segment is missing in this instar as in all succeeding instars.

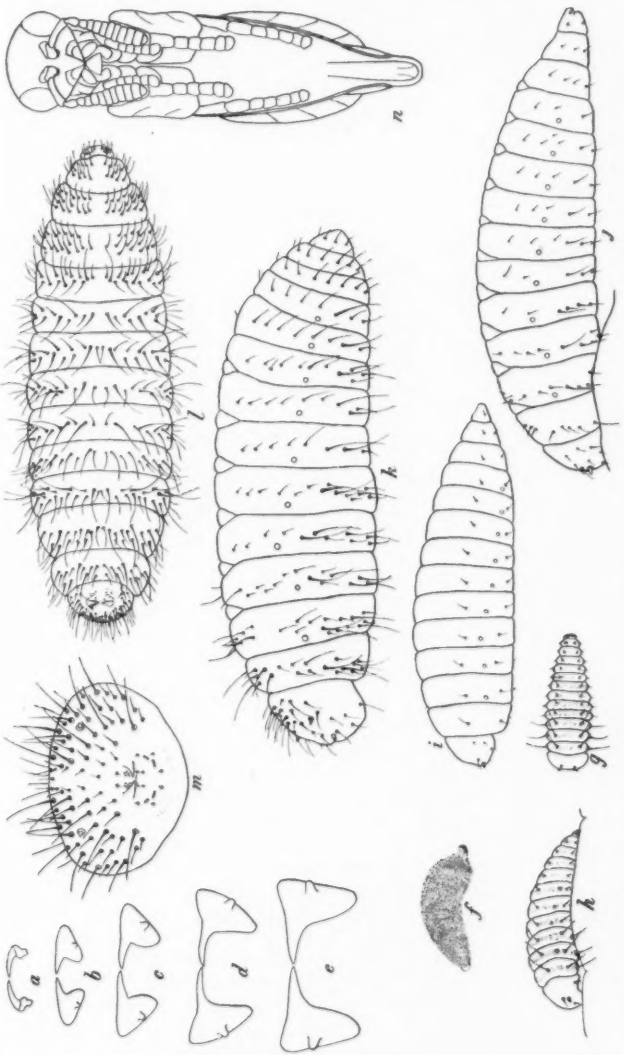

FIG. 5.—*Eridontomerus isosomatis*: *a*, Mandibles of first-instar larva; *b*, same of second-instar larva; *c*, same of third-instar larva; *d*, same of fourth-instar larva *e*, same of full-grown larva; *f*, egg; *g*, newly hatched larva (dorsal view); *h*, larva just before first molt (lateral view); *i*, second-instar larva (lateral-dorsal view); *j*, third-instar larva (lateral view); *k*, fourth-instar larva (lateral view); *l*, full-grown larva (ventral view); *m*, head of full-grown larva showing position of antennae, mouth parts, sensoria, and sensory hairs; *n*, pupa of female. All greatly enlarged

The head is somewhat intermediate in shape between those of the first instar and the full-grown larva. The head capsule is very feebly chitinized; the head and body are translucent-whitish. The head bears twelve sensory hairs located as follows: A pair just above the

mandibles, a pair between and slightly above the antennae, three on each lateral face, and one just posterior to each mandible. The hairs on one side of the head only are shown in the illustration. The antennae are about twice as long as broad; the mandibles feebly chitinized and triangular in outline. Each of the thoracic segments bears three sensory hairs on each side, and each abdominal segment two hairs on each side, with the exception of the last (tenth) segment, which apparently has only one. The sensory hairs are arranged as follows: A tergal and a lateral row the full length of the body and a sternal row in the thoracic region. There are nine pairs of open spiracles.

The average length of six larvae was 0.88 mm. and the average greatest width 0.233 mm.

Third Instar

Like the second instar, the third does not resemble the full-grown larva; it (fig. 5, *j*) is slenderer, much less hairy, and the hairs are not so long but are more prominent than in the second instar.

The head and body are colored as in the previous instar. The head bears 16 sensory hairs, arranged as shown in Figure 5, *j*. The hairs on one side of the head only are shown in this sketch. The antennae are about twice as long as wide and proportionately more prominent than in the second instar; the mandibles (fig. 5, *c*) are triangular in outline and feebly chitinized. There are nine pairs of open spiracles. The thoracic segments bear a row of sensory hairs around the entire segment; the first, third, and sixth abdominal segments bear on each side 6 hairs each; the second, fourth, and fifth bear 5 hairs each; the seventh, ninth, and tenth bear 3 hairs and the eighth 4 hairs.

The average length of six larvae was 1.216 mm., and the average greatest width 0.38 mm.

Fourth Instar

At this stage the larva (fig. 5, *k*) is more nearly like the full-grown larva than at any other time. The sensory hairs are about as prominent as in the full-grown larva, but they are not nearly so numerous. The larva is not so slender and pointed as in previous instars, but subcylindrical, tapering only very slightly toward each extremity. There are 13 body segments in addition to the head; the head is somewhat cone-shaped in lateral profile with mouth parts as the point of the cone; the larva is translucent whitish, but brownish in the vicinity of the mandibles; the antennae are about twice as long as broad; the sensory hairs of the head are numerous and quite prominent; the mandibles are triangular and rather strongly chitinized. The body segments are about equal in length with the exception of the last three or four segments of the body; each body segment has a row of hairs around it; those in the thoracic region especially have the appearance of irregular double rows. There are nine pairs of open spiracles.

The average length of eight larvae was 1.63 mm., and the average greatest width 0.50 mm.

Full-Grown Larva

The full-grown larva (fig. 5, *l*) is cylindrical, gradually tapering toward each extremity; it is dirty whitish, often with a dark central area caused by the presence of food in the digestive tract; it is brownish in the mandibular region; the head is almost hemispherical; the mandibles are on the ventral side and point downwards; the antennae are distinctly longer than wide and cone-shaped. The head (fig. 5, *m*) is rather densely covered with coarse sensory hairs of varying length. The labrum is a triangular piece and has a pair of very small sensory hairs near the base, and apparently there are 5 sensory papillae on each side near the angle of the mouth. The ventral mouth parts together form a fused region, which anteriorly is trilobed, corresponding to the component median labial and the two lateral maxillary regions. This fused region (fig. 5, *m*) bears 20 sensory hairs and organs, arranged as follows: 2 sensory hairs or papillae and 2 groups with 3 ring-shaped organs on each lateral or maxillary region and 4 sensory hairs on the median or labial region. This whole fused region is convex. The mandibles (fig. 5, *e*) are triangular in outline, rather heavily chitinized, and dark brown. Each body segment bears one or more irregular rows of long, stout hairs around it, the hairs being most numerous on the anterior and posterior segments. There are nine open spiracles.

The average length of five full-grown larvae was 2.37 mm. and the average greatest width 0.75 mm.

The full-grown larva of this species resembles very closely that of *Ditropinotus aureoviridis* Craw. The distinguishing characteristic of the larva of this species is the dense covering of prominent setae on the front of the head. This is in contrast to the larva of *D. aureoviridis* the head of which is marked with a rather distinct, narrow, centrally located line down the front, which is without setae.

The young larva begins to feed as soon as it pushes its head out of the eggshell and usually continues to feed in this manner for several hours before it completely extricates itself. Apparently it slightly punctures the body wall of the host with its mandibles and then begins to suck up the body fluids. The larvae feed almost continuously, if undisturbed, until nothing remains of the host larva except the empty, dry skin. On the other hand, an individual host larva seems to furnish just enough food for a single parasite. In the field as many as five eggs have been found upon one host. The young larvae, however, are cannibalistic upon occasion and all observations indicate that only one individual ever matures in a single Harmolita cell.

The manner of locomotion is similar to that of other Harmolita parasites. The duration of instars varied from less than a day to 2 or 3 days, varying directly with the temperature of the air and the condition of the host. Thirty-four larvae became full grown in from 4 to 8 days, and the average was 5.58 days during July and August of 1920 and 1921. Two mature larvae remained quiescent 12 and 14 days, respectively, before pupating during the same season. Many larvae of both the first and second generations became full grown in cell slides but died before any of them pupated. Some of these individuals remained in apparently good condition for 17 months and died 4 or 5 months later.

PUPA

Pupation takes place very rapidly. The small number of individuals reared to adults in glass cell slides did not afford an opportunity to observe the process of pupation. No excrement is voided until the larva contracts preparatory to entering the prepupal stage. When entering upon the prepupal stage the first four segments of the abdomen contract equally until each is somewhat less than half its usual length in the full-grown larva. At first the pupa (fig. 5, *n*) is a very delicate brown in color, gradually changing and becoming very dark, approximating the color of the adult insect.

The pupal period of two individuals observed in glass cell slides was 9 and 11 days, respectively. Two female pupae averaged 3.04 mm. in length and 0.78 mm. in greatest width. One male pupa measured 2 mm. in length and 0.58 mm. in greatest width.

ADULT

The adults of this species, both males and females, resemble *Ditropinotus aureoviridis* more closely than any of the other parasites of Harmolita. The female can readily be distinguished from that of *D. aureoviridis* by its dark abdomen and the male by its dark-colored femora and tibiae.

Two generations of this parasite occur normally in Virginia. This seems to hold for Indiana also and is probably true throughout its range, although this can not be stated definitely. The adults of the first generation emerge in June and in Virginia those of the second generation emerge the last week in July. Males normally occur, but the females seem to greatly outnumber them. Females of this species are deuterotokous. The winter is passed as full-grown larvae in the cells of Harmolita. Oviposition is similar to that described for *D. aureoviridis*.[18] The egg, after oviposition, has the same shape as before. Upon dissection, the abdomens of female adults have been found to contain as many as eight well-developed eggs which were apparently ready for deposition.

One individual has been found to deposit as many as 6 eggs in one day. A total of 12 eggs was secured from one individual which had a preoviposition period of 11 days and lived 30 days under as favorable cage conditions as could be provided. In other instances the preoviposition period was 4 days.

The average time required for development from egg to adult during the same season for two individuals was 32 days.

[18] PHILLIPS, W. J., and POOS, F. W. LIFE-HISTORY STUDIES OF THREE JOINTWORM PARASITES. Jour. Agr. Research 21: 405–426, illus. 1921.

A CANKER OF APPLE AND PEAR TREES CAUSED BY GLUTINIUM MACROSPORUM, N. SP.[1]

By S. M. ZELLER

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INTRODUCTION

Fries first erected the genus Glutinium to contain one species, *G. exasperans*, which was considered to belong in the Stilbaceae because of its cylindrical synemaform fruiting bodies which were later found to be pycnidia. In 1894 Starbäck[2] emended the genus and placed it in its rightful position in the Sphaeropsidales. He transferred to the genus the two Fresian species *G. laevatum* (Fr.) Starb. [*Sphaeria laevata* Fr.] and *G. palinum* (Fr.) Starb. [*Phoma palina* (Fr.) Sacc.], *G. exasperans* Fr. being reduced to a synonym of the former. Originally, *G. palinum* was reported on Salix in France and Sweden and *G. laevatum* on *Prunus padus* in Sweden. As far as the present writer can find, no other species has been added to this interesting genus, although McAlpine[3] found one on gumming twigs of peach in 1900. This he referred to *G. laevatum*, although the spores measured only $3.5 \times 1\,\mu$.

DESCRIPTION OF FUNGUS ON HOST

In the summer of 1920 the writer found a Glutinium on apple bark in the vicinity of Corvallis, Oreg. This was cultured on potato-glucose agar and sweet clover stems, upon which pycnidia were formed. The material collected was so meager, however, that it was laid aside until more could be had. Late in March, 1924, pear twigs were received from Hood River, Oreg. The tissues around the buds of these were affected by blistery cankers which also extended into the internodes. Cultures from these cankers yielded the same Glutinium observed from apple in 1920.

It was at this time that the writer looked up earlier accessions in the department of botany and plant pathology of the Oregon Agricultural College. He found that in 1912 H. L. Rees, then research assistant of the Oregon Agricultural Experiment Station, had observed the fungus on branches of pear trees in the college orchard and at Salem, Oreg. His complete notes on cultures, inoculation, and the morphology of the fungus have greatly aided in its identification and have made portions of this paper possible. On September 27, 1926, F. D. Bailey discovered this fungus on an apple tree in Marion County, Oreg. This collection is typical of the fungus and is made the basis of the following description.

The cankers with which this organism has been found associated are similar in appearance to winter-injury cankers which have been

[1] Received for publication Dec. 10, 1926; issued April, 1927.

[2] STARBÄCK, K. STUDIER I ELIAS FRIES' SVAMPHERBARIUM. I. "SPHAERIACEAE IMPERFECTE COGNITAE." p. 58–59, illus. Stockholm. 1894. (Bihang Till K. Svenska Vet.-Akad. Handlingar, Bd. 19, Afd. 3, no. 2.)

[3] MCALPINE, D. FUNGUS DISEASES OF STONE-FRUIT TREES IN AUSTRALIA AND THEIR TREATMENT. 165 p., illus. Melbourne. 1902.

subsequently invaded by the black-rot organism, *Physalospora malorum* (Peck) Shear, the pycnidia, however, being extremely different in appearance. Rees reports a canker on pear about 5 feet long, extending along the upper side of a scaffold branch (fig. 1), while cankers on apple from 4 to 8 inches long have been observed. The edges of the cankers are usually regular. The dead areas of bark inhabited by the fungus are dry and extend to the discolored wood beneath. The fruiting bodies appear in any region of these dead areas, many times in cracks, or breaking and pushing through the epidermis. When the unbroken epidermis is pulled away the cylindrical pycnidia underneath appear in some instances as vertical columns supporting the raised overlying epidermis. In moist weather the pycnidia under such conditions are somewhat villous and olive green.

FIG. 1.—Side branch of pear tree showing long, narrow Glutinium canker extending along the upper surface. Photograph by H. L. Rees

INOCULATIONS

On May 28, 1912, Rees made nine inoculations and as many checks in pear trees. His notes are as follows:

The bark was washed clean with a 1–1,000 solution of mercuric chloride and dried by wiping with a rag with which the solution had been applied. With a sterile scalpel incisions were made and in one a bit of the fungus from a pure culture was inserted. Both of the wounds were then covered with grafting wax by applying with a hot scalpel, the grafting wax having previously been made sterile by boiling. On June 13, 1912, five more inoculations were made in the same manner. In a little more than a month death of the tissue around the point of inoculation was apparent. The epidermis blistered and the affected area became dark in color. By the first of September these areas had become definitely outlined by a crack around the edge of the dead area, which had become sunken. At this time it was seen that all of the 14 inoculations had taken and all checks had remained unaffected and healed over. (Fig. 2.) Four of the inoculated areas were beginning to fruit and by the first of December all showed the fruiting bodies pushing up through the epidermis. They appeared first as black conical bodies and gradually pushed up until about 1 millimeter in height. By the first of January it was seen that spores were escaping from the pycnidia and that the fungus was fruiting in all the inoculated areas. The outlines of the dead areas were slightly irregular, and the dead areas were dry and hard, and extended to the xylem, discoloring it for a depth of about 2 or 3 millimeters. The size of the areas affected from inoculation varied from 2.5 to 3.5 × 3 to 12.5 centimeters. The areas varied from elliptical to circular in shape. Two sets of isolations were made from these cankers, and in every (14) case the same fungus was recovered.

These inoculations show that this Glutinium is at least a wound parasite on pear, capable of considerable growth in apparently healthy bark during the dormant period of the host. Cankers on apple, which have been seen more recently, show the organism capable of considerable growth in healthy bark.

MORPHOLOGY OF THE FUNGUS

The pycnidia are about 1 to 2 millimeters in height, almost cylindrical, tapering upward, so that the diameters are about 0.6 to 0.8 millimeter at the base and 0.24 to 0.4 millimeter at the ostiole. Seldom are they so short as to appear cone-shaped. (Fig. 3.) In cross section the pycnidia are circular to slightly elliptical. In dry weather the pycnidia are covered with a white, flaky exudate giving the black cylinders a whitish sheen. (Figs. 4 and 5.) The hyaline spores exude at the apex in a flinty, translucent globule. When moist the pycnidia are olive green to black and the globule of spores shows white and glistening. Rees states that "the pycnidia arise in the collenchyma under the epidermis and in growing push up through the epidermis and carry some of the collenchyma cells up with them, so that in the mature pycnidium lines of these cells may be seen arched up into the base of the fruiting body." (Figs. 6 and 7.) When full grown the pycnidia are almost entirely superficial, only the base being embedded in the outer layer of collenchyma cells and the epidermis peeled back or adhering to the sides of the base. (Fig. 5.) The pycnidia usually appear singly but may come in groups of two or three.

FIG. 2.—A, pear-bark cankers produced by inoculation with *Glutinium macrosporum*. These inoculations, made in May, showed pycnidia in December of the same year. B, uninoculated lesions made at the same time as the inoculations in A. Photographs by H. L. Rees

The base of the pycnidium and about the lower third of the side walls are of a hyaline pseudoparenchyma. Above this the side walls are composed of very compactly interwoven hyphae with a vertical trend. The exterior is carbonaceous, gradually becoming hyaline and less compact toward the interior (fig. 8) where the interwoven hyaline hyphae of the wall give rise to the conidiophores within.

The conidiophores branch off from the upward-growing wall hyphae nearly to the ostiole. In the same manner hyphae from the inner wall at the edges of the ostiole grow out, forming a fringe of protruding, ostiolate hairs, which are sparingly branched and septate.

FIG. 3.—Section of the bark showing pycnidia of *Glutinium macrosporum*. × 1.5. Photographed by H. L. Rees

In the base of the pycnidium, hyphae from the walls may form more or less prominent fascicles covered with conidiophores. Where these are prominent the vertical sections of the base appear as divided into locules or pockets. With rejuvenated growth, younger pycnidia may occasionally grow up through older ones, producing a double-walled effect, as shown in Figure 7. The outside of the interior wall in such a case differs only from the newer inside wall by the fact that the interwoven hyphae are more compact and are more carbonaceous. Spores are borne only within the inner cavity and not on the outer layer. The broken wall of the older pycnidium may not extend around the whole younger pycnidium but may be sloughed off or may appear on one side only.

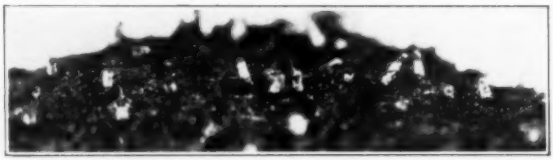

FIG. 4.—Pycnidia of *Glutinium macrosporum* enlarged to show cylindrical shape and the whitish exudate on the surface. × 4

The spores are acrogenous, ellipsoid, one-celled, hyaline, usually one-guttulate, with a slight thickening of the cell wall at the point of attachment. (Fig. 9.) The spores measure 15 to 28 $\mu \times 8$ to 10.5 μ. In certain culture media, as mentioned below, microconidia are formed. These are cylindro-ellipsoid, hyaline, 6 to 10 $\mu \times 2$ μ.

CULTURAL CHARACTERISTICS

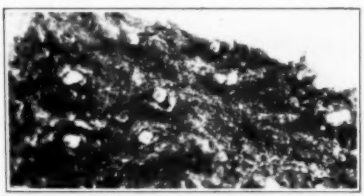

FIG. 5.—Pycnidia breaking through the epidermis of the bark. × 4

Cultures of this Glutinium were grown on potato-dextrose agar, prune agar, Lima-bean agar, corn meal, sweet-clover stems, pear and apple stems, and such liquids as beef broth and decoctions of beans and prune. Although the organism showed some growth on all of these media the more solid media proved best for luxuriant growth or fruiting. The greatest growth was made on corn meal, Lima-bean agar, and apple, pear, and sweet-clover stems, and on all of these some type of sporulation was produced. Only on sweet-clover stems were typical pycnidia produced in culture. The spores in these, however, were smaller than are found in nature on the host, measuring only 13 to 17 $\mu \times 7$ to 8 μ. On the other better media, such as apple

stems, Lima-bean and prune agars, two types of spores were formed. The mycelium appears as a white appressed growth, which takes on a

FIG. 6.—Longitudinal section of a pycnidium of *Glutinium macrosporum*. × 70. Photograph by H.L Rees

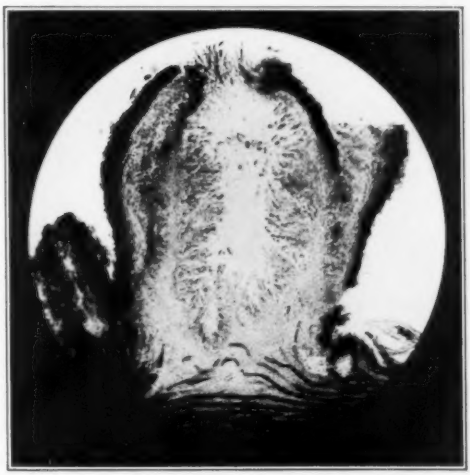

FIG. 7.—Longitudinal section of a pycnidium of *Glutinium macrosporum* which has grown up through an older pycnidium, the outer wall of which has been broken away on one side and become more or less incorporated with the wall of the younger pycnidium on the other side. The paraphysate csticle is prominently shown. × 70. Photograph by H. L. Rees

drab color as minute pustules appear in concentric rings which finally coalesce. Over the surface appear glistening globules composed almost entirely of spores, which are borne on branched conidiophores

on the surface of the mycelial mat. The larger spores are about 18 to 22 $\mu \times 8 \mu$ and the smaller ones 6 to 10 $\mu \times 2 \mu$.

SPORE GERMINATION

Spores from pycnidia on the host readily germinate on a damp microscopic slide in a damp chamber, or in hanging drops of nutrient agar or sterile water.

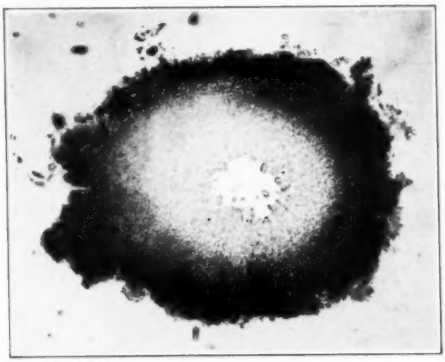

FIG. 8.—Cross section of a pycnidium. × 70. Photograph by H. L. Rees

FIG. 9.—Spores of *Glutinium macrosporum*. × 500. Photograph by H. L. Rees

Germination takes place within 18 hours. One or more germ tubes may develop from a spore. The first indication of germination is the formation of transverse lines across the spore. These are not septa but mark the edges of circular segmentation of the cell wall. These transverse cracks in the cell wall open up, exposing the protoplasmic membrane from which the germ tube or primordial hyphae emerge unobstructed. This is faintly shown in Figure 10. The germ tubes always emerge from these transverse cracks in the cell wall, never from the end of the spore. The germ tubes are

extremely granular and begin septation early. Although repeated attempts to germinate them were made, the microconidia formed in cultures were not seen to do so.

APPLE FRUIT ROT

A fruit rot produced by this organism has not been found in the orchards, but when apples are inoculated a fruit rot is always induced. Ten apples each of three varieties, Newtown Pippin, Jonathan, and Grimes Golden were inoculated, two inoculations and a check being made on each apple. After two weeks small, soft, tan-colored, rotted areas appeared about the inoculations, but the checks remained sound. In six weeks' time the decayed spots had increased to about 4 centimeters in diameter, and had sunken and become darker at the centers, with even definite margins. After nine weeks the apples were well decayed and the organism was reisolated from all the apples. No fruiting of the fungus occurred on the apple fruit. Rees had similar results with five inoculations on two apples. This species of Glutinium therefore is not only a wound parasite, causing a canker of pear and apple, but is capable of causing apple fruit rot.

TAXONOMY AND DESCRIPTION OF FUNGUS

From the study of the morphology of this fungus there is little question that it belongs in the genus *Glutinium* Fr. emend. Starb., and that it is an undescribed species. The only two species previously described have very much smaller pycnidia and spores. Accordingly, the species under consideration will be described as *Glutinium macrosporum*.

Glutinium macrosporum, n. sp.

Pycnidia, olivaceous to black, drying with a white, flaky exudate, cylindrical, often tapering upward, 1 to 2 millimeters high, 0.6 to 0.8 millimeter diameter below, 0.24 to 0.4 millimeter diameter above, ostiolate; walls of pycnidia pseudoparenchymatous below, of compactly interwoven hyphae above, of carbonaceous exterior, and hyaline within; cavity cylindric, lined with simple to slightly branched conidiophores; edges of the ostiole paraphysate; spores ellipsoid, hyaline, one-guttulate, 15 to 28 × 8 to 10.5 μ.

On bark of apple and pear trees in western Oregon. Type collection in Zeller herbarium (No. 6964) and in the herbarium of the department of botany and plant pathology, Oregon Agricultural College, Corvallis, Oreg. (No. 4852).

FIG. 10.—Germinating spores of *Glutinium macrosporum*, showing false septation, which is really a transverse breaking of the wall. ×125. Photograph by H. L. Rees

Because of the size of the spores and the type of pycnidium, this species is closely allied to some species of Macrophoma, but no species in that genus has characters like *Glutinium macrosporum*. The slight branching of the conidiophores suggests Dendrophoma also, but from the other characters it was thought best to refer it to Glutinium.

SUMMARY

A new species of Glutinium has been found occurring on the bark of apple and pear trees in western Oregon. When inoculated into the bark of pear, the fungus proved to be a wound parasite developing a bark canker which extended into the wood beneath. The morphology of the fungus on the host, and cultural and spore germination characteristics on artificial media are described.

A fruit rot of apple is produced by artificial inoculation. The organism is described as *Glutinium macrosporum* Zeller n. sp.

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